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ENGINEERING:

An Illustrated Weekly Journal.

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For Boilers of all types.
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Tubes AND Fittings AND Steel Plates.
STEWARTS AND LLOYDS, Ltd.
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See Advertisement, page 24. 1111

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REFRIGERATING PLANT. 1475
See Advertisement, page 51, Sept. 14.

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PRODUCED
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LATHE WORK up to 10 ft. diameter.
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Centrifugals.
Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND.
639
See half-page Advertisement, page 66, Aug. 31.

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Founded 1854 by Sir WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 1311

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Professor: F. C. LEA, D.Sc., M.Inst.C.E., M.I.Mech.E., M.I.Met.

Courses in Civil Engineering leading to the Degree of B.Sc. and Higher Degrees, also courses in Civic Design and Town Planning. The new Session will commence on October 1st, 1923.
Full particulars and syllabus can be obtained from Professor Lea, or from the undersigned.
GEO. H. MORLEY,
Secretary. B 579

The Yarrow Scholarships.

The COUNCIL of the INSTITUTION OF CIVIL ENGINEERS are PREPARED to CONSIDER APPLICATIONS for NOMINATIONS to the above SCHOLARSHIPS.
These should be submitted before the 1st October, 1923, to the SECRETARY of the Institution, at Great George Street, Westminster, S.W. 1, from whom the detailed regulations may be had on application.
The Yarrow Scholars must be British subjects who, desiring to become Engineers, lack sufficient means to enable them to pursue their practical or scientific training.
The Scholarships are of a value varying from £50-£100 per annum. B 162

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DAY COURSES.

FULL-TIME (DAY) COURSES extending over three or four years, and leading to the Diploma of the College, are arranged in the following Departments:—
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CIVIL ENGINEERING, ARCHITECTURE AND BUILDING.
ELECTRICAL ENGINEERING.
BIOLOGY.
These Courses are designed to meet the needs of Students wishing to present themselves for the Degree Examinations of the London University.
Special Facilities are available for Advanced Study and Research.
Further particulars and prospectuses may be obtained on application to the PRINCIPAL, Technical College, Bradford. B 594

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Principal: ROBERT H. PICKARD, D.Sc., F.R.S.
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Evening Classes Suitable for Final B.Sc. (Eng.), A.M.I.C.E., A.M.I.M.E., etc., are held in the following subjects:—
STRENGTH OF MATERIALS with LABORATORY TESTING. THEORY OF STRUCTURES and STRUCTURAL DESIGN. THEORY OF MACHINES and MACHINE DESIGN. HEAT ENGINES with LABORATORY TESTING. HYDRAULICS with LABORATORY TESTING.
Students enrolled from September 18th.
DAY TECHNICAL COLLEGE.
Full Time Courses in MECHANICAL, CIVIL, and ELECTRICAL ENGINEERING for B.Sc. (Eng.) Degree, (UNIVERSITY OF LONDON) or COLLEGE DIPLOMA commence September 24th. ENTRANCE EXAMINATION commences September 18th. Fee: £18 per session. A higher fee will be charged to students not residing in London.
Full Particulars of all classes on application to the PRINCIPAL. B 512

The University of Sheffield.

SESSION 1923-24.

Vice-Chancellor: Sir HENRY HADOW, C.B.E., D Mus., LL.D.

DEPARTMENTS OF MECHANICAL, ELECTRICAL AND CIVIL ENGINEERING, METALLURGY MINING, FUEL TECHNOLOGY, AND GLASS TECHNOLOGY.

The Courses in the DEPARTMENT of ENGINEERING extend over three or four years and prepare students to become Mechanical, Electrical, Civil or Mining Engineers, or specialists in Fuel Technology or Glass Technology.
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The LECTURE COURSES in all the Departments are supplemented by practical Training in Laboratories and Workshops, which are fully equipped for the purpose of advanced scientific teaching, investigation and research.
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The LECTURE COURSES commence OCTOBER 3rd, 1923.
The TECHNICAL LABORATORY COURSES commence SEPTEMBER 25th, 1923.
For further details of the Courses and for particulars of the Degrees, Associateships, Diplomas, and Certificates awarded on their successful completion, application should be made to
W. M. GIBBONS,
Registrar.
B 444

ROYAL AIRCRAFT ESTABLISHMENT.

An Examination for the

Entry of TEN TRADE LADS to the above establishment will be held on Tuesday, 16th October, 1923. Application for admission to the examination must be made on the prescribed form which must be filled in and returned not later than Wednesday, 10th October.
Application forms and the regulations governing the conditions of entry and training of Trade Lads may be obtained by post from
THE SUPERINTENDENT,
Royal Aircraft Establishment,
South Farnborough,
Hants,
or by personal application at the Royal Aircraft Establishment Employment Department. B 681

LONDON COUNTY COUNCIL.

Westminster Technical INSTITUTE.

Vincent Square, S.W.1.

Principal: J. STUART KER, B.Sc., A.M.Inst.C.E.

Session 1923-4.

CIVIL ENGINEERING.

Evening Sessional Courses to give systematic instruction to Civil Engineers in STRUCTURAL ENGINEERING, REINFORCED CONCRETE DESIGN, SURVEYING AND LEVELLING, HYDRAULICS, SPECIFICATIONS, QUANTITIES AND ESTIMATES, ENGINEERING MATHEMATICS, ETC., will begin on 24th September, 1923. Students should enrol during the preceding week.
In addition, SPECIAL ADVANCED SESSIONAL COURSES intended for those well grounded in the principles of STRUCTURAL DESIGN have been arranged as under:—
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JAMES BIRD,
Clerk to the London County Council.
B 576

Northern Polytechnic INSTITUTE,

Holloway, London, N. 7.

DEPARTMENT OF ARCHITECTURE, SURVEYING & BUILDING.

Special classes in Structural Engineering, Reinforced Concrete and Graphic Statics.

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TUESDAY, SEPTEMBER 25th, 1923.
Fee for attendance three evenings per week—£1 10s.

B 677

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Inst. Civil Engrs., Inst. Mech. E., London Univ. (Matric., Inter., B.Sc.), and All ENGINEERING EXAMINATIONS personally conducted by Mr. TREVOR W. PHILLIPS, B.Sc. (Honours), Assoc. M.Inst.C.E., M.R.S.I., F.R.S.A., &c. Also Day Tuition in Office. Excellent results at all Exams. Courses may commence at any time, and all Students receive individual tuition.—For full particulars apply to 8/11, TRAFFORD CHAMBERS, 58, SOUTH JOHN STREET, LIVERPOOL. 1296

Engineering Salesmanship

and SALES MANAGEMENT.—Write for brochure describing our special Course of training for posts of unlimited scope in this lucrative field.—DIRECTOR, Institute of Engineering Salesmanship, 333, Oxford Road, Manchester. 1587

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Civil Engineer GIVES INSTRUCTION, by post, in the Computation of Stresses in Girders, Columns & Trusses.—B 472, Offices of ENGINEERING.

TENDERS.

HOPPER BARGE.

The Trustees of Shoreham Harbour invite

Tenders for the Supply and

DELIVERY of a suitable HOPPER BARGE (new or good second-hand), capable of carrying about 200 tons of Dredged material. Full particulars as to age, condition and price to be sent to the undersigned on or before Saturday 29th September inst.
The Trustees do not bind themselves to accept the lowest or any Tender.
CRANFIELD BAGULEY,
Clerk to the Trustees.
Harbour Offices,
Southwick, Brighton.
18th Sept., 1923. B 675

NEW ZEALAND EAST COAST MAIN TRUNK RAILWAY.

KAITAIA, AONGATETE, APARIA AND TE PUNA SECTIONS.

THE PUBLIC WORKS DEPARTMENT, Wellington, N.Z., is inviting

Tenders for the Construction

of the above SECTION of approximately 18 miles length.
A complete Set of Specifications, Conditions of Contract and Drawings may be seen, by appointment, at the offices of THE BRITISH ENGINEERS' ASSOCIATION (Incpted.), 32, VICTORIA STREET, LONDON, S.W.1.
The work includes the Complete Construction of the Railway; i.e., Bushfelling, Clearing, Construction of all Earthworks, Culverts, Fencing Permanent Way, Station Buildings, Yards, Bridges, etc., etc.
The closing date for acceptance of Tenders at Wellington, N.Z., is 18th March, 1924.
The date for completion of the work is three years from acceptance of Tender.
THE BRITISH ENGINEERS' ASSOCIATION (Incpted.),
32, Victoria Street,
London, S.W. 1.

Telegrams: Yinco chi, Sowest, London.
Telephones: Victoria 1276-1277-8039. B 654

DOMINION OF NEW ZEALAND.

18-MILE RAILWAY CONSTRUCTION TENDERS.

Tenders Close with the

PUBLIC WORKS TENDERS BOARD, Wellington, New Zealand, at NOON on 18th MARCH, 1924, for construction of 18 miles of railway, including bridges, station buildings, earthworks, approach road metalling, etc. Plans and specification may be inspected at the Office of the HIGH COMMISSIONER FOR NEW ZEALAND, 415, Strand, London, W.C. 2. B 685

CHEADLE AND GATLEY URBAN DISTRICT COUNCIL.

ELECTRICITY SCHEME.

The Cheadle and Gatley Urban District Council invite

Tenders for:—

SUB-STATION SWITCHGEAR. Contract No. 9.
Copies of Specification with Form of Tender, General Conditions and Drawings can be obtained from Mr. C. H. WORDINGHAM, C.B.E., M.Inst.C.E., M.Inst.B.E., either at 7, Victoria Street, Westminster, S.W.1, or 33, Brazennose Street, Manchester.
A deposit of Three Guineas is required which will be returnable provided that a *bona fide* Tender be submitted and not withdrawn. Duplicate specifications will be supplied on payment of One Guinea per copy, which sums are not returnable. All cheques to be made payable to the Engineer.
Tenders, enclosed in an envelope sealed with wax, and clearly endorsed "Tender for Sub-Station Switchgear," must be addressed to the undersigned at the Council Offices, Cheadle, Cheshire, and be delivered not later than Ten a.m. on Monday, October 8th, 1923.
The Council does not bind itself to accept the lowest or any Tender.
By Order,
JOHN H. JOHNSON,
Clerk of the Council.
Council Offices,
Cheadle, Cheshire. B 656

Tenders Will be Received

at the Office of the Colonial Secretary in Singapore, S.S., on or before the 30th November, 1923, due allowance being made for delays on the Post,
For the following works:—
NEW GENERAL POST OFFICE, SINGAPORE.
Any person applying for a form of Tender must deposit the sum of £10 with THE CROWN AGENT FOR THE COLONIES, 4, Millbank, S.W.1.
Drawings, Specifications, Quantities and Contract Documents may be seen and Forms of Tender obtained, at the Office of the Crown Agents between the hours of Ten a.m. and Four p.m.
Tenders must be addressed to the Colonial Secretary, Straits Settlements, Singapore, to reach him by 30th November, 1923. The successful Tenderer must undertake to find if required, security to the amount of $100,000 (Straits) which will be returned when the reserve deducted from certificates amounts to a like sum.
Tenders must be marked "Tender for New General Post Offices, Singapore," and must be on the printed form issued by the Crown Agents.
In the event of any person whose Tender has been accepted failing within thirty days from the date of acceptance to enter into the necessary contract or deposit the security required under the Contract for its due fulfilment, the sum deposited may be forfeited to the Crown.
Tenders sent to Singapore from overseas must be accompanied by the priced Schedule of Quantities forwarded to the Colonial Secretary, Singapore, S.S.; in separate sealed packets marked with the name and address of the Tenderer. The priced Schedule of Quantities of the successful Tenderer only will be opened for examination, in all other cases the Schedules will be returned unopened.
The Government does not bind itself to accept the lowest or any Tender. B 593

APPOINTMENTS OPEN.

Resident Engineer

REQUIRED by the KINGSTON (JAMAICA) GENERAL COMMISSIONERS for the Hermitage Hydro-Electric Scheme, for three years with possible extension. Salary, £720 per annum with free quarters and passage. Candidates not over 40 years of age, should be qualified civil engineers with experience on construction of dams and water turbine installation, in dealing with contracts and contractors and, if possible, some electrical and municipal experience.
Apply at once, in writing, giving brief details of qualifications and experience, and stating age, to THE CROWN AGENTS FOR THE COLONIES, 4 Millbank, London, S.W.1, quoting M/11854. B 686

RANGOON UNIVERSITY.

A Professor and a

LECTURER in Civil Engineering are REQUIRED for Rangoon University, Burma. Candidates for the Professorship should be under 40 years old (preferably not more than 35), and for the Lectureship not more than 30. Salary on the ordinary scale of the Indian Educational Service. The Officers appointed will also receive Burma allowance and Rangoon compensatory allowance. The Professor will, in addition, receive a special professorial allowance of Rs. 300 per mensem. The Professor will be required to commence duty in February, 1924, and the Lecturer in June, 1924. Full particulars as to pay and allowances can be obtained from the Board of Education.—Applications or inquiries should be addressed, in covers marked "C.A.," to the BOARD OF EDUCATION, Whitehall, London, S.W.1.
Scottish candidates should apply to the SECRETARY, Scottish Education Department, Whitehall, London, S.W.1. B 688

THE POLYTECHNIC, 309, REGENT STREET, W.1.

Wanted, an Assistant Master.

Good honours degree, or equivalent qualifications essential.
Mechanical Drawing and Mechanics essential. Mathematics subsidiary.
Salary in accordance with Burnham Scale for Technical Teachers, less 5% agreed deduction.
Forms of application, which should be returned on or before 5th October, may be obtained from the DIRECTOR OF EDUCATION. B 696

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large Engineering establishment. Good education, wide experience of modern methods, knowledge of accurate work, exceptional organising ability and knowledge of labour problems essential. Address, B 655, Offices of ENGINEERING.

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the POST of GENERAL MANAGER of Steam Wagon Works. Applicants must have the special Engineering knowledge and trade experience required for this position, and must also have good organising ability both in regard to output and sales. Apply, by letter, stating age, experience, and salary required to THE SECRETARY, Yorkshire Patent Steam Wagon Co., c/o CLAYTON, SON & Co., LTD., Moor End, Hunslet, Leeds. B 693

DOCK GENERAL MANAGER.

Palmers (Swansea) Dry Dock

Company, Limited, REQUIRE a GENERAL MANAGER for their business at Swansea. Only one who has held a position of General Manager in such a Works, or a Shipbuilder or Engineer having experience in ship and engine repairing work need apply. Good references essential. Age 30 to 45.—Applications, which must be by letter only, and will be treated in confidence, to be addressed to PALMERS SHIPBUILDING & IRON CO., LTD., Hebburn, marked outside, "Application — Dock Manager." B 694

Required for India, Manager

of General Engineering Works. Applicants must have held similar responsible position in British Works and capable handling large staff, and should have good all-round general engineering knowledge including constructional work and mining machinery. Also knowledge modern costing systems and commercial engineering. Three years' agreement. Salary Rs. 1,200 monthly first year, Rs. 1,300 second, Rs. 1,400 third, also free house, light and coal. Write stating age, experience, and copy testimonials to BOX P.G.A., care of DAVIES & Co., 95, Bishopsgate, E.C. 2. B 546

Assistant Engineer

REQUIRED by the GOVERNMENT OF THE GOLD COAST for the Public Works Department, for a tour of not less than 12 nor more than 18 months' service. Salary, £480, rising to £720 a year by annual increments of £20, and thence to £920 a year by annual increments of £40. Outfit allowance of £60 on first appointment. Liberal leave in England on full salary. Free quarters and passages. Candidates, about 35 years of age, preferably single, must be qualified Civil Engineers, have had special experience in surface water and land drainage work and surveying.
Apply at once, by letter, stating age, qualifications, whether married or single, and experience, to the CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W.1, quoting M/12100. B 687

Assistant Civil Engineers

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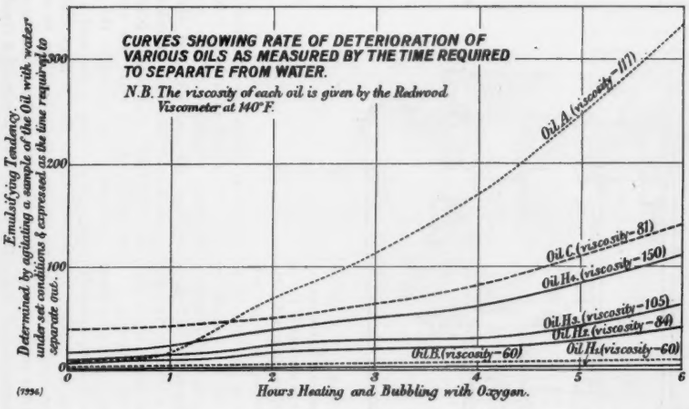
DETERIORATION OF TURBINE OILS IN USE.

ALEXANDER DUCKHAM, F.C.S., M.I.P.T., and STANLEY E. BOWREY, B.Sc., F.C.S.

TURBINE construction has now reached such a high standard of excellence that the lubrication of the main bearings approaches the ideal more nearly than in any other lubricating problem commonly met with. Fluid friction is diminished by the use of thin oils, and metallic contact is absolutely prevented by an efficient forced-feed system. In consequence, many turbine bearings run for years at high speed without exhibiting any appreciable sign of wear. The principal source of trouble lies in the tendency for condensed steam from the glands, or water from the cooling system, to find its way into the oil in quantities large enough to hinder the proper functioning of the oil. The problem, therefore, is to secure oil which will separate readily from water, and will retain this property during the long period of use, thus enabling the water to be drawn off at intervals instead of being suspended in the oil and circulated to the bearings. In some instances turbines are run on what is in fact an emulsion of oil and water, and it is found that so long as the amount of water does not exceed a certain proportion, which may be as high as 15 per cent. or 20 per cent. of the oil, no trouble is experienced. The principal risk involved lies in the possibility of water settling out to an extent sufficient to cause the pump to draw water only. This is most likely to occur after the machine has been standing, and, consequently, the accepted practice is to drain all separated water from the sump immediately before starting, although where a large settling tank is provided the possibility of water alone being picked up is reduced.


CURVES SHOWING RATE OF DETERIORATION OF VARIOUS OILS AS MEASURED BY THE TIME REQUIRED TO SEPARATE FROM WATER.
N.B. The viscosity of each oil is given by the Redwood Viscometer at 140° F.
Emulsifying Tendency. Determined by agitating a sample of the Oil with water under set conditions & expressed as the time required to separate out.
300
200
100
0
Oil A (viscosity – 177)
Oil C (viscosity – 81)
Oil H2 (viscosity – 150)
Oil H3 (viscosity – 105)
Oil H1 (viscosity – 84)
Oil B (viscosity – 60)
Oil H4 (viscosity – 60)
0
1
2
3
4
5
6
Hours Heating and Bubbling with Oxygen.
(7994)

It might be reasoned that a satisfactory manner of overcoming the trouble would be to use an oil possessing the property of readily emulsifying with water, thus ensuring the presence of a uniform mixture in the sump, and guarding against unmixed water being supplied to the bearings. No doubt this system would serve for a time, but there is a limit to the amount of water which can safely be allowed in such emulsion, and if the oil were of the type which does not separate at all, it would have to be removed whenever the percentage reached this limit. It is, therefore, desirable to go to the other extreme and to select oil which separates from water as rapidly as possible, the sump then being drained of all intruded water at regular intervals. Great trouble is experienced with the oil which separates slowly from water, since in getting rid of the latter, the oil is unavoidably drawn off also and wasted.

The leading manufacturers of turbine oil have long had in use methods for determining the facility with which their products will separate from water after being churned up in a manner resembling that which obtains in the circulating system of a turbine. These methods vary from simply shaking up by hand with water in a bottle and observing the rate at which oil and water separate, to carefully standardised tests in which a paddle of definite dimensions revolves at a given speed in measured quantities of oil and water, and the resulting emulsion is measured after a fixed period of settling, or, the rate of separation is determined by the aid of a gauge and stop watch.

Investigation reveals that certain refining processes are particularly valuable in reducing the tendency of oils to emulsify, but another fact of great importance is now appreciated and explained; it is that certain crudes, owing to their chemical composition, yield oils possessing greater resistance to the deteriorating action of air than others. Until recent years it was believed that air had no action on refined petroleum products, except at high temperatures, or at least that any action which did take place was so slight as to be negligible in practice. It is now recognised that oxidation proceeds, even at normal temperatures, and considerable attention has been devoted to the characteristics of the products formed. The earliest text-books on petroleum taught that the lamp oils and lubricating oils consisted of substances belonging to the "paraffin" series of hydrocarbons, which are characterised by their inertness, but it has since been shown that true members of this series having molecular weight over 198 (tetradecane) are not liquids, but solids, although in boiling point they may correspond to liquid lubricants which are now known to consist of less highly-saturated hydrocarbons, including olefines and naphthenes. These are capable of reaction with oxygen, yielding at first substances which are soluble in the oil, and later insoluble substances which appear in the form of a brown or yellow solid, a product well known to users of oil-cooled transformers, and which, incidentally, represents the first stage in the formation of solid deposits in cylinders, crank chambers, &c. of internal-combustion engines. These oxidation products play an important part in the formation of oil-water emulsions and their separation. Emulsions depend for their permanency upon the maintenance of a film at the surface separating the oil and water globule. The molecular forces brought into play at the surface between the two liquids, hinder the rupture of the surface, and it has been shown that certain colloidal substances, when present, concentrate at the surface and help to maintain it intact. The oxidation products of oil are substances of this emulsion-forming character, and when they are combined with the alkalies which sometimes occur in water the property becomes still more marked. The annexed diagram shows how the formation of oxidation products renders the emulsion more lasting. For instance, in the case of "A" the time of break-up for a litre of emulsion was 8 minutes. The same oil after 1 hour's oxidation, yielded an emulsion which took 17 minutes to break, and after 6 hours' oxidation the emulsion (still produced by the same amount of agitation) required 5 hours and 33 minutes to break.

The resistance of an oil to the action of air depends upon its chemical constitution. The removal of impurities is generally sufficient to produce a temporarily non-emulsifying oil, but resistance to oxidation depends on the constitution of the oil and, consequently, products refined from different crudes with equal care may be equally satisfactory at first, but whereas one will remain satisfactory over a long period of use, the other will quickly develop a tendency to emulsify. The curves bring out this distinction very clearly. They indicate the time required for a litre of oil to separate from the emulsion formed by stirring with half its volume of distilled water under standard conditions. Other things being equal, the thinnest oil will take the least time to separate, since it allows the water to fall more freely, and it is interesting to notice that with the four high-class oils, H.1, H.2, H.3 and H.4, ranging in viscosity from 60 to 150 at 140° F., the rate of separation remains very roughly in the same ratio throughout. The starting point indicates the time of separation for the fresh oil, and the rest of the curve indicates the increasing time required when the oil has undergone oxidation for varying periods.

In the case of "A," the rate of separation is at first equal to that of H.2, and slightly quicker than that of H.3, which approximates to it in viscosity, but after oxidising for an hour, it becomes slower than that of H.3, and thereafter becomes still slower, the quality at the end of 6 hours' oxidation being much inferior to that of any other oil under consideration.

Curve "B" represents a light oil having the same viscosity as H.1; when fresh, its rate of separation is rapid, the time required being equal to that of H.1. Under the oxidation treatment, the time increases to double that of H.1; in other words, "B" shows a greater falling off in quality.

Curve "C" represents an oil of viscosity equal to that of H.2. There is obviously something amiss with this make of oil, since in the fresh condition the time of separation is eightfold that of the high-class grade H.2. It does not, however, show unduly rapid increase, but resembles rather the curve of a fairly good oil which has already undergone partial deterioration.

Whilst deterioration due to atmospheric action on the warm oils is the principal cause of emulsification, other circumstances contribute their ill effects; for instance, excessive access of water or the provision of a sump of inadequate dimensions for settling, may result in the circulating pump picking up too much water in spite of the oil being of excellent quality. Again, the entrance of impure water, such as cooling water containing alkalies, may result in secondary actions which render it difficult for the oil to disengage itself. Another not infrequent source of trouble lies in the fine dust which sometimes accumulates in the oil; this dust may be of atmospheric origin, or it may arise from the corrosion of some part of the machine, and it is not by any means uncommon to find floating particles of finely-divided ferric oxide in the sump of a turbine. Such oxide undoubtedly comes from the combined influence of air and water on metallic dust formed by attrition in the circulating pump or, may be, by actual rusting of iron surfaces with which the oil and water come into contact.

Chemical analysis of the emulsion proves helpful in identifying such sources of trouble and should in any case form part of the investigation.

THE SHIPPING ENGINEERING AND MACHINERY EXHIBITION AT OLYMPIA.

(*Concluded from page* 331.)

MESSRS. JOHN I. THORNYCROFT AND CO., LIMITED, Thornycroft House, Smith-square, S.W. 1, are exhibiting a new design of marine motor suitable for installation in open launches, small cabin cruisers, canal barges, &c., as well as for use as auxiliary power in sailing yachts and similar craft. The engine, which is illustrated in Figs. 82 to 90, on pages 354 and 355, runs on either petrol or paraffin, developing about 9 h.p. with the former fuel and about 7½ h.p. with the latter, but it differs from the majority of engines of this size now on the market in having only two cylinders instead of four. This, of course, considerably reduces the total number of working parts and gives a simpler and more reliable power unit. The design also includes a combined reducing and reversing gear, so that when travelling full speed ahead the propeller runs at only 700 r.p.m., and can therefore be made larger and more efficient,

MARINE MOTOR WITH COMBINED REDUCING AND REVERSING GEAR AT THE OLYMPIA EXHIBITION.

CONSTRUCTED BY MESSRS. JOHN I. THORNYCROFT AND CO., LIMITED, ENGINEERS, LONDON.

Fig. 82.

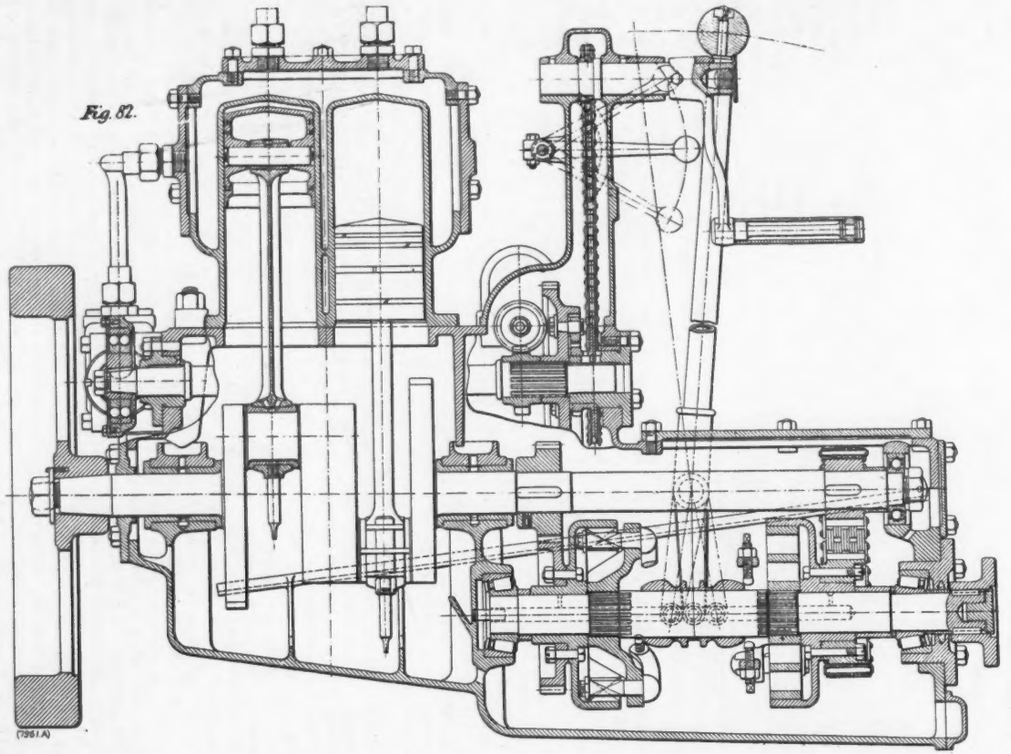
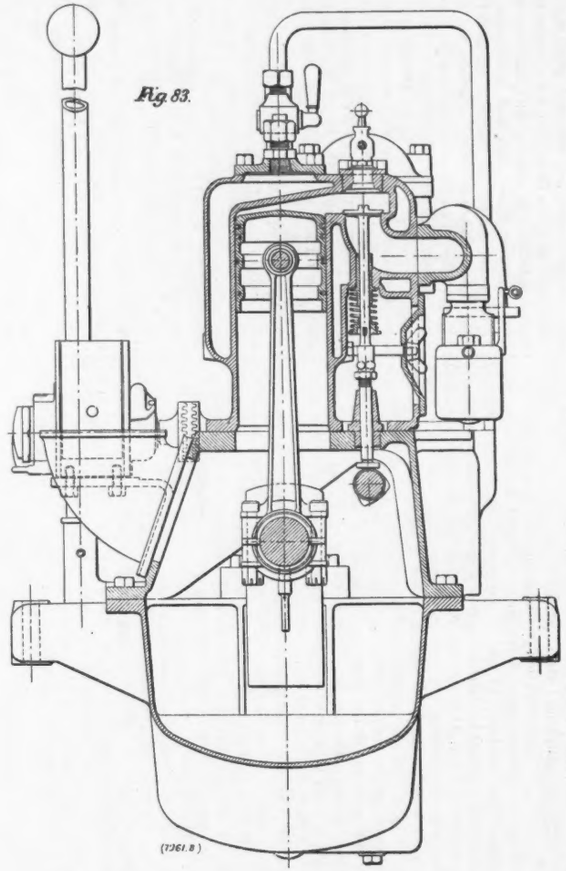


Fig. 83.



than if driven directly from the engine at from 1,000 r.p.m. to 1,300 r.p.m., as is common practice.

The general design can be followed by examining the longitudinal and transverse sections reproduced in Figs. 82 and 83, respectively, while its appearance is well shown by the photographic illustrations Figs. 84 and 85 on the opposite page. The cylinders are of 3½ in. bore and the stroke of the pistons is 4½ in., but the design of both cylinders and pistons can easily be followed from the drawings, and calls for no particular comment. The gudgeon pin is of hardened steel, ground after hardening, and the connecting rods are steel stampings fitted with phosphor-bronze bushes at the small ends, and having the big-ends lined with white metal. The crankshaft is a mild steel forging machined all over with the cranks set at 180 deg., as shown in Fig. 82. It is formed in one piece with the first shaft of the reducing and reversing gear, and has a cast-iron flywheel, 18 in. in diameter, mounted on the forward end. The after end of the shaft is supported by a ball bearing, while the main bearings are of white metal. The camshaft is of hardened steel ground on the cams and journals, and the valves are made from nickel steel stampings. As shown in Fig. 83, the valve tappets and springs are enclosed in a pocket fitted with a cover which is held in position by a stud and flynut. The magneto used for ignition is driven through spiral gearing from the after end of the camshaft, as will be clear from Fig. 82, and from Fig. 83 it will be seen that a flexible vernier coupling is fitted on the magneto shaft to enable the ignition timing to be accurately adjusted.

Boats of the type in which such engines as that which we are now describing are fitted, are frequently used in shallow waters containing a considerable quantity of sand and other gritty matter in suspension, and if the ordinary gear-type rotary pump is employed for circulation purposes under these conditions, trouble is usually experienced from excessive wear. To obviate this, Messrs. Thornycroft have fitted a plunger pump which, as shown in Fig. 82, is driven from the forward end of the camshaft by means of a large "Skefko" ball-bearing eccentric. Sections of the pump are reproduced in Figs. 88 and 89, and the plunger is shown separately in Fig. 90. In order to reduce the noise and shock which generally accompany the working of pumps of this type, the stroke has been made short and the diameter of the plunger large, these dimensions being ½ in. and 1¾ in., respectively; the valves are also of large diameter and small lift, as will be clear from Figs. 88 and 89. It will also be noticed that the eccentric rod is connected to the plunger by means of a small ball bearing of the same type as used for the eccentric itself. Screw-down grease cups are fitted to the housings of both bearings for lubrication, so that the pump can run for long periods without attention. The reducing and reversing gear, above referred to, is most clearly shown in the longitudinal section, Fig. 83, annexed. The gear is enclosed in a casing cast integrally with the engine crank-case; access to the interior of the casing is provided by covers on top and at the after end. As will be clear from the illustration, the propeller shaft is supported at each end by "Timken" roller bearings, which take the thrust in both directions of running. By means of the two expanding friction clutches shown, the propeller shaft can be connected to the crankshaft extension either through a pair of sprocket wheels and a silent chain at the after end, or through a pair of spur wheels with helical teeth at the forward end. The former constitutes the ahead drive and gives a

reduction ratio of 11 : 7, while with the reverse drive through the spur gears the reduction ratio is about the same. Either clutch can be put into engagement by means of a cam-sleeve sliding on the propeller shaft and operated by a ball-ended hand lever, as will be clear from Fig. 83, which shows the lever in

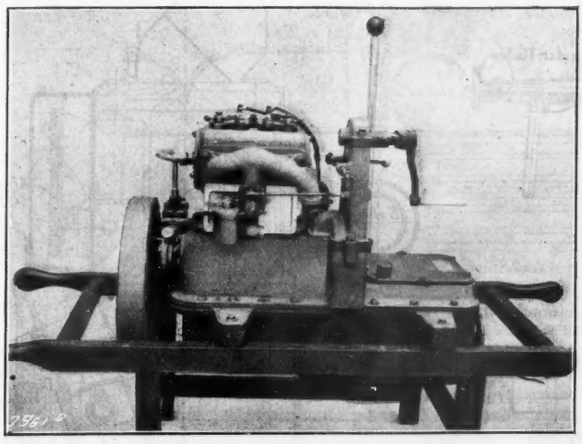


FIG. 84.

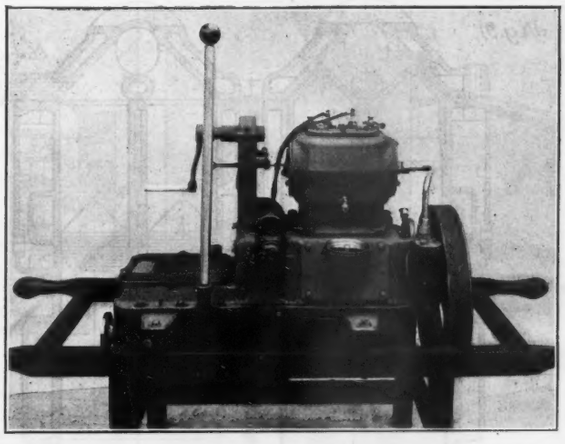


FIG. 85.

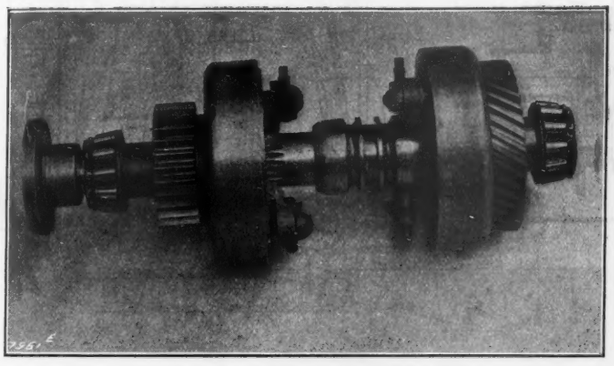


FIG. 86.

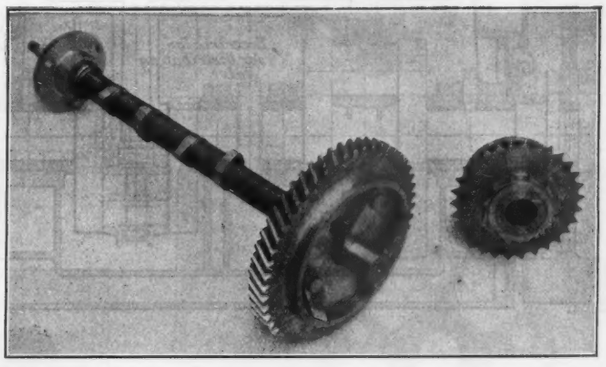
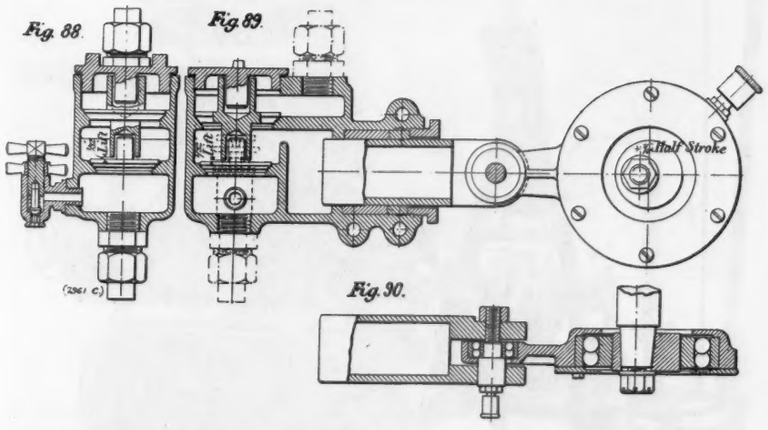


FIG. 87.



FIGS. 84 TO 90. DETAILS OF MARINE MOTOR; MESSRS. JOHN I. THORNYCROFT AND CO., LIMITED, LONDON.

the intermediate position with both clutches disengaged so that the engine can run freely. The propeller shaft complete, but removed from its casing, is illustrated separately in Fig. 86, the ahead drive being shown on the left of this illustration and the astern drive on the right.

The lower part of the reducing and reversing gear casing forms the oil sump for the lubrication system which is operated on the splash principle. Oil from the sump is picked up by the clutch drums and thrown by centrifugal force on to two sloping galleries, one of which is fixed on each side of the casing. These galleries, one of which is shown in Fig. 82, lead the oil to a trough formed in the crank-case under the forward cylinder, and the surplus from the trough flows into a second trough under the after cylinder, the excess finally returning to the gear casing through the passage shown in Fig. 82. Splashers fitted on to the big-ends of the connecting rods supply the oil to the cylinders, big-ends and main bearings, troughs being formed on the caps of the latter to collect the oil which drains down the crank-case walls. The gear-case is provided with a pipe and dipper rod, so that the level of the oil in the sump can be easily ascertained.

The starting gear is of the usual ratchet and pawl type operating on the camshaft through a roller chain and sprocket wheels, the mechanism being completely enclosed as shown in Fig. 82. The ratchet wheel is made in one piece with the sprocket wheel, which runs freely on a sleeve supporting the end of the camshaft, and the pawls are fitted on the half-speed wheel which forms the camshaft drive. This wheel, we may mention, gears with the astern-drive pinion on the crankshaft extension. The pawls are held in engagement with the ratchet teeth, for the operation of starting, by means of light springs, but when the engine is running the pawls are thrown outwards by centrifugal force and thus kept clear of the teeth. Reference to Fig. 87, which is reproduced from a photograph of the camshaft with the sprocket wheel and ratchet removed, will make the arrangement of the parts quite clear.

For running on petrol, a carburettor of the "Solex" type is supplied, and the throttle control is conveniently mounted on the casing containing the starting gear, as shown in Figs. 84 and 85. The guaranteed consumption of petrol, when running at full power, is 0·75 lb. per brake horse-power hour and the corresponding figure for paraffin is 0·80 lb. The total weight of the equipment illustrated is 5 cwt. and the overall length from the flywheel to the face of the propeller shaft coupling is 37¾ in. The extreme width over the bearer lugs is 21½ in. and the height from the bottom of the oil sump to the top of the starting gear casing is 30 in.; the reversing lever extends upwards another 8 in.

In conclusion, we may mention that a 72-hour

HOT-BULB "RECORD" OIL ENGINE AT THE OLYMPIA EXHIBITION.

CONSTRUCTED BY MESSRS. ROBERT HEATH AND LOW MOOR, LIMITED, ENGINEERS, BRADFORD.

Fig. 91.

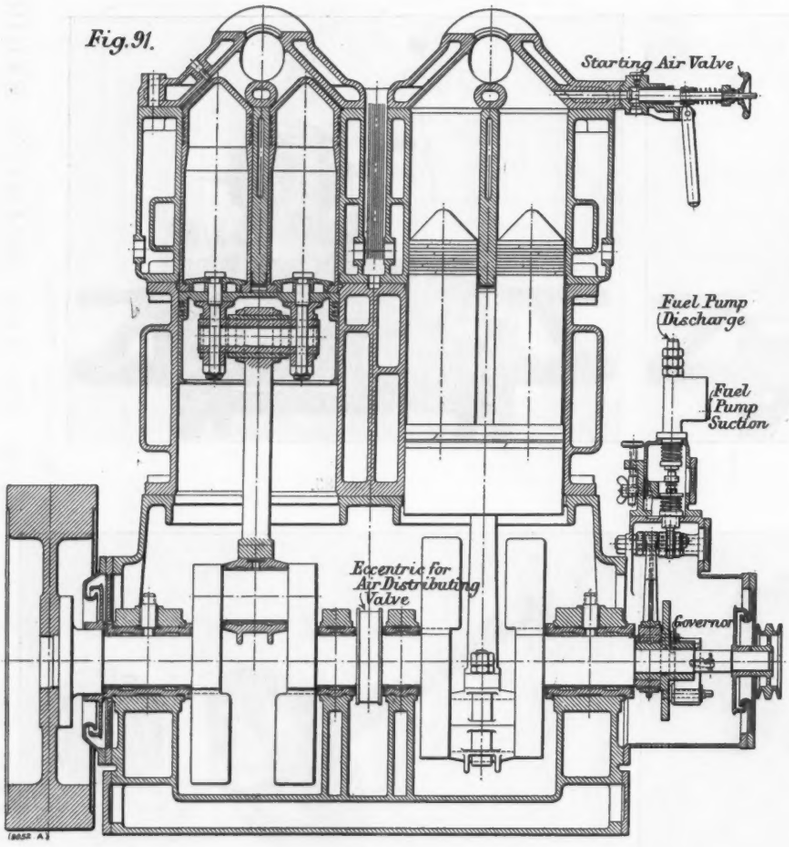
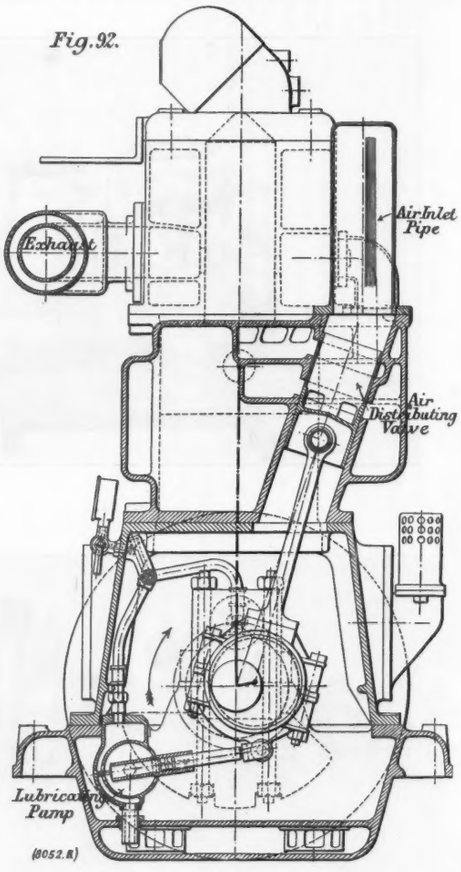


Fig. 92.



reliability test of one of these engines was recently carried out at the makers' Basingstoke works by request of the Admiralty, and under the constant supervision of Admiralty overseers. The engine was run continuously at full power for the time mentioned, the power being measured by a Heenan and Froude dynamometer coupled to the propeller driving shaft of the reducing gear, so that the losses in the latter would not be included in the readings. The speed was determined by a revolution counter connected to the dynamometer shaft by a roller chain, and readings of the fuel and oil consumption were taken at hourly intervals. The fuel used was Grade 3 petrol having a specific gravity of 0·74 at 60 deg. F., and the total consumption for the whole test was 62·55 gallons, or 466·75 lb. The average brake horse-power recorded was 9·31, so that the fuel consumption works out at 0·696 lb., or 0·752 pint per brake horse-power per hour. The total consumption of lubricating oil was 25 pints, and the cooling water used amounted to 144 gallons per hour, the temperature rise being 34 deg. F. The engine ran steadily throughout the test, the revolutions of the propeller shaft ranging from 703 to 713 per minute, and having an average value of 707·4 per minute. This, we think, must be regarded as a very creditable performance for a comparatively small engine.

Messrs. Robert Heath and Low Moor, Limited, of Bradford, Yorkshire, are exhibiting a hot-bulb crude oil engine, of the "Silent Record" type, which is illustrated in Figs. 91 to 93, on the present page. The engine is interesting by reason of its mechanical design which differs entirely from the usual type of hot-bulb engines. It works on the two-cycle principle, and develops 50 b.h.p. at a speed of

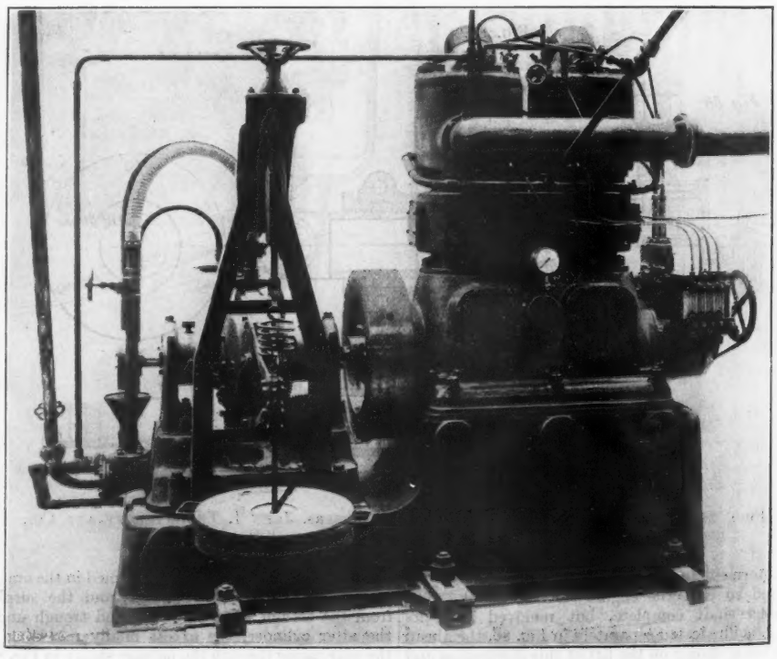


FIG. 93.

SELF-CLEANING OIL STRAINER AT THE OLYMPIA EXHIBITION.

CONSTRUCTED BY THE AUTO-KLEAN STAINERS, LIMITED, ENGINEERS, LONDON.

Fig. 94. PART SECTIONAL VIEW THRO' A.B.

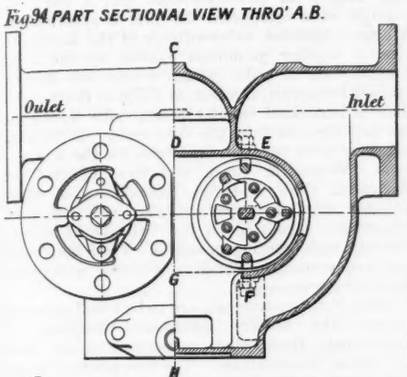


Fig. 95. PART SECTION THRO' C.D.E.F.G.H.

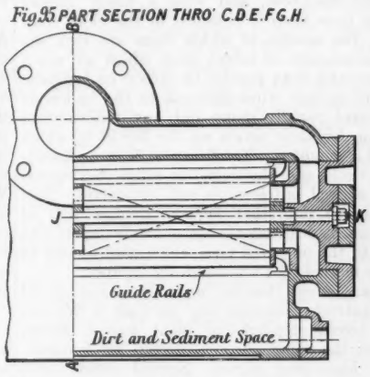
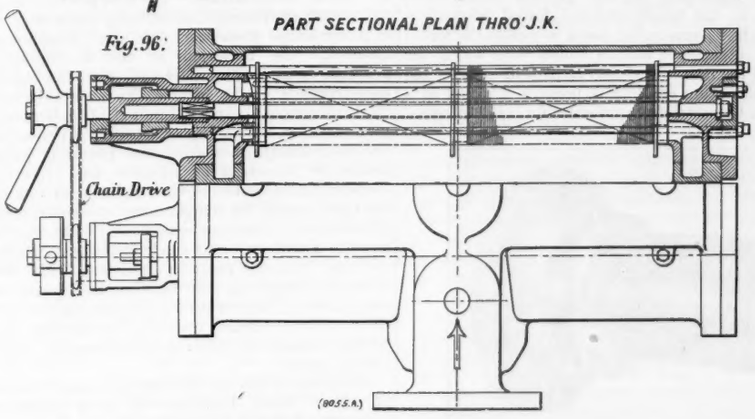


Fig. 96. PART SECTIONAL PLAN THRO' J.K.



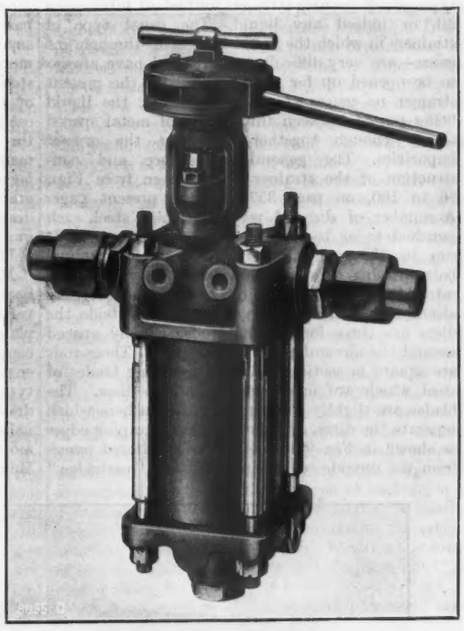


FIG. 98.

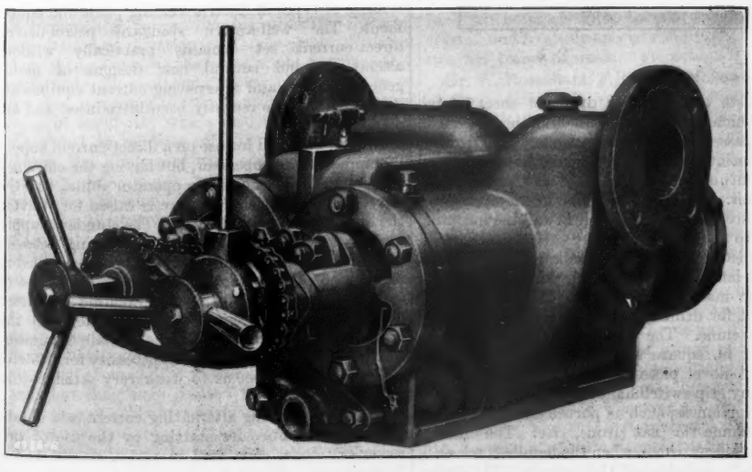


FIG. 97.

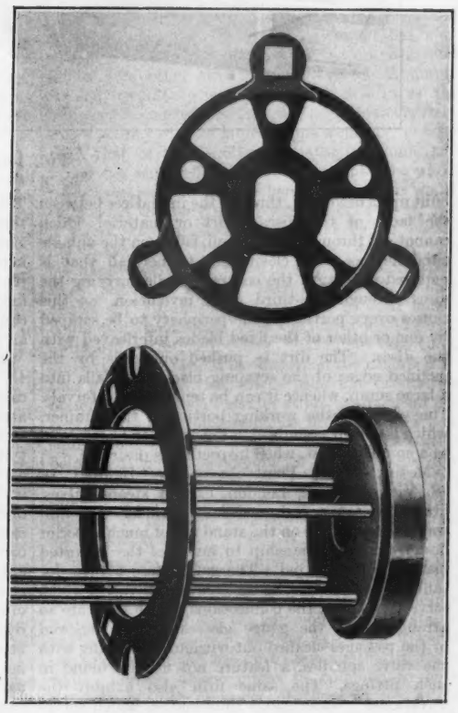


FIG. 99.

450 r.p.m. Referring to Fig. 91 it will be seen that what may be called the main piston of each line carries on its top face two smaller pistons, each of which works in a cylinder of its own. These working cylinders are connected together at the top by means of a combustion space which is common to the two. When the main piston rises, the working pistons compress the charge in their cylinders, in the usual way, but the main piston also compresses air as it moves upwards, delivering the air at a pressure slightly above that of the atmosphere into the belt round the lower part of the cylinders. As the pistons we have been considering reach the top of their stroke, ready for the firing of the mixture, those of the other line are arriving at the lowest point of their travel with the pressure of the exploded charge behind them. One of the working pistons at this point uncovers the exhaust ports and the charge escapes. The other working piston then uncovers the inlet air ports, and the air which has been compressed in the belt by the rise of the piston on the other line is allowed to flow through these air ports by the action of the air-distributing valve. This latter valve is situated between the two lines of cylinders and is operated by an eccentric, as shown in Fig. 92. The incoming air rushes up one working cylinder, through the combustion space and down the other cylinder, escaping by the still open exhaust ports after having swept along with it the whole of the products of combustion. The scavenging of the working cylinders is thus most efficiently carried out, and they are quite filled with fresh cold air for the next stroke. The working cylinders are $5\frac{1}{2}$ in. in diameter, and 10-in. stroke, and develop, as already mentioned, 50 b.h.p. at 450 r.p.m. The absence of crank-case compression is an important feature of the type, as it enables forced lubrication to be employed. The fuel consumption of the engine is about 0·6 lb. per brake horse-power hour, and

about 0·005 pints of lubricating oil are used per hour. Engines of this type are built in sizes from 15 b.h.p. upwards for land or marine purposes, and are designed to fulfil Lloyd's requirements.

Messrs. Auto-Klean Strainers, Limited, of 1A, New London-street, London, are showing various types of self-cleaning strainers for fuel oil, lubricating oil, or indeed any liquid. The usual type of strainers in which the liquid is passed—through fine gauze—are very difficult to clean, and have always to be opened up for the purpose. In the present strainer no gauze at all is employed, the liquid being passed between thin sheets of metal spaced closely enough together to arrest the grosser impurities. The general appearance and construction of the strainer will be seen from Figs. 96 to 100, on page 357 and the present page. A number of discs of very thin sheet steel, each punched so as to have five arms connecting the rim to the centre, are strung on longitudinal bolts passing through the arms. They are separated from each other by thin washers strung alternately with them, on the bolts. Outside the discs are three longitudinal rods, equally spaced around the circumference of the discs. These rods are square in section and carry scraping blades of steel which are interleaved with the discs. The blades are slightly thinner than the washers which separate the discs, and have inclined scraping edges as shown in Fig. 99. The oil to be filtered passes from the outside to the inside of the "cartridge" built up as described, through the interstices between the faces of the discs. Dirt or material which cannot get through with the oil, is left on the outside circumference. To clean the strainer, all that is required is to turn the central spindle carrying the discs through one-third of a revolution, as this causes every portion of the periphery to be scraped by one or other of the fixed blades interleaved with the discs. The dirt is pushed outwards by the inclined edges of the scraping blades and falls into a large sump, whence it can be removed at intervals. The whole of the working portion of the strainer, which is shown assembled in Fig. 100, can be removed as a complete unit, when inspection is desirable.

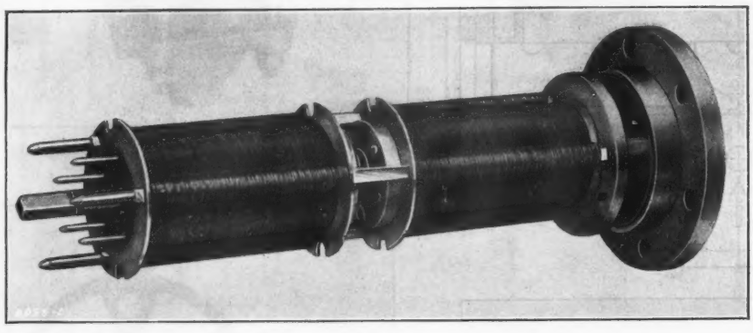


FIG. 100.

Messrs. Steam Plant Accessories, Limited, of 38, Victoria-street, London, exhibit steam valves, fittings, injectors and gauges of all kinds. The full-way or gate valves on the stand are of much superior design and workmanship to much of the imported material of this kind. The gauge-glass fittings for tanks deserve notice, as the screwdown valves which serve to shut-off the connections to the tank are so arranged that the gauge glasses can be renewed or the passages cleaned out without interfering with the valve spindles, a feature not usually found in such fittings. The same firm also exhibit the "National" water-gauge illuminator, which serves to show the water level in a gauge glass in a very effective manner. An electric lamp of the "Linolite" type is fitted in a brass tube behind the gauge glass, and the only escape for the light is through a narrow longitudinal slit at the back of the glass. The refractive effect of the water makes the whole of the glass below the water level appear brightly luminous, while above the water level there is just a thin line of light. The result is to render the water-level thoroughly distinct even when the gauge is examined from considerable distances.

Messrs. Henry Hughes and Son, Limited, of 59, Fenchurch-street, London, whose name is known all over the world as makers of ship's compasses sextants and navigating instruments generally, are showing a new design of compass which is extraordinarily dead-beat, and with a much greater directive force than is obtained in the older compasses. The needles of which there are two, are small bar-magnets of cobalt steel, which are much more powerful than needles of carbon or tungsten steel, and springy wires fastened to the underside of the card rapidly damp out any tendency to oscillation by their action on the liquid in which the card is mounted. The firm also show an assortment of clocks and chronometers which they manufacture, as well as telescopes and binoculars. It is gratifying to note that Messrs. Hughes' sets of draughtsmen's instruments are not only superior in quality to the imported ones which used almost to hold the market, but are decidedly cheaper.

Messrs. James Howden and Co., Limited, of Scotland-street, Glasgow, are showing a 250-kw. turbine-driven ship-lighting plant and a 30-kw. plant for the same purpose, driven by a direct-coupled high-speed engine. Several other small engines of the totally-enclosed forced lubrication type are to be seen on the stand, as well as the forced draught fittings for marine boilers with which the name of the firm is so closely identified. One of the most interesting exhibits is perhaps a model of a Howden-Ljungström air preheater for boiler furnaces. This consists of a cellular drum of sheet metal, through which the incoming air and the hot waste gases are passed in reverse directions. The drum is kept in continuous slow rotation so that the heated part is continually passed on to the path of the incoming air. By this means flue gas temperatures can be reduced to about 220 deg. F. and the incoming air raised to about 400 deg. F.

The Lanston Monotype Company, Limited, of 43, Fetter-lane, London, are showing adding and calculating machines, and also the "Radbore" attachment for drilling square holes in an ordinary drilling machine. The device will drill holes from $\frac{3}{8}$ in. to $1\frac{1}{2}$ in. square with either sharp or filleted corners. A novel piece of apparatus on the stand is the Denny grip-switch handle for small electrically-operated appliances, such as portable drills, vacuum cleaners, domestic flat irons, &c. The handle contains a trigger which, when the handle is released, automatically switches off the current. The design is such that it is impossible to open the electric circuit slowly, however gradually the handle is released. Nothing happens until the trigger has been allowed to come out of the handle sufficiently far, and then a small quick-break switch inside the handle interrupts the current. The switch is suitable for all currents up to 250 volts and has a capacity of 5 amperes. The value of the device in economising current in domestic appliances is obvious, and the impossibility for unattended apparatus to be left unintentionally in circuit eliminates one of the risks of fire due to overheating.

Among the manufacturers of steam-raising plant are Messrs. Babcock and Wilcox, Limited, Farringdon-street, London, whose principal exhibit is a mechanical stoker of the chain-grate type, although an illuminated water-gauge, in which the rays of a concealed electric lamp behind the glass are directed upwards through the water by means of a shutter on the Venetian blind principle, is well worthy of attention on account of its simplicity and effectiveness. Messrs. John Thompson (Wolverhampton), Limited, of Wolverhampton, show models of their straight tube boilers for power-stations, and a full-sized example of a corrugated flue and a superheater. A large cylindrical water-softener of the Kennicott type is another prominent exhibit by the firm. Another firm of boiler makers present are Messrs. Spencer-Bonecourt, Limited, of Hitchin, Herts., who show a horizontal tubular boiler, with horizontal gas jets directed into the tube ends. A thermal efficiency of 85 per cent. is claimed for the arrangement. Messrs. E. Green and Son, Limited, of Wakefield, show cast-iron economisers of their ordinary standard type and also with the tube connections reinforced on the "ringstay" system for very high working pressures. Their horizontal cast-iron economiser for service above water-tube boilers is shown as well.

Boiler-house instruments are to be found on many stands. The Foster Instrument Company, of Letchworth, Herts, show pyrometers of all types and for all temperatures. The firm produce simple and robust instruments for ordinary commercial use in power-houses or on board ship, the "disappearing filament," the radiation, or the thermoelectric principle being employed according to the class of measurements to be made. The Cambridge and Paul Instrument Company, Limited, of 45, Grosvenor place, London, have a very fine display of pyrometers and temperature measuring and recording instruments for industrial or scientific use. Electrical distance thermometers of the indicating and recording types, enable the temperatures at selected points all over a ship, power-house or factory to be observed at some central spot on a single instrument, which is switched from one point to another at will. Electrical CO_2 indicating and recording instruments are also shown. These require no chemical absorbents, their action depending upon the cooling effect on a heated filament of different percentages of CO_2 in the flue gases.

The Premier Electric Welding Company, Limited, of Abbey Wood, London, S.E. 2, a constituent company of Nobel Industries Limited, is showing a range of types of electric welding plant and equipment. The well-known standard petrol-driven direct-current set remains practically without alterations, but several new designs of motor generator plant and alternating current equipments on new lines have recently been introduced and are on show.

A plant designed for use on a direct-current supply by more than one operator, but having the efficiency characteristic of the single operator units, has the novel feature that the pressure is raised for starting the arc by means of a booster. The standard supply for working is given at a pressure varying between 30 and 40 volts, but the boosting dynamo coupled in series with it adds another 35 volts at the time of starting. The instant that the welding is started a contactor device cuts out the booster and the whole supply is obtained from the main generator. This method of eliminating the necessity for wasteful resistance control seems to work very satisfactorily in practice.

The corresponding alternating current sets obtain their high pressure for starting by the use of two secondary coils, connected in series, on the transformer core. The main coil gives a pressure of about 30 volts and the starting one an additional potential difference of between 45 and 50 volts. When no current is passing the coils are joined in series, but the moment that the arc is struck and current passes, it is used to operate a contactor switch to cut out the starting coil. To prevent the rapid fluctuations of current which would otherwise take place and to stabilise the welding processes a choking coil is used in the welding circuit.

The premier electrodes are the outcome of the experimental work of Dr. J. H. Paterson, and although flux coated, have such a nature and so thin a covering that it is claimed that the necessity for chipping away slag does not arise.

In bringing to a close our notice of the Exhibition, we should mention that our review of the stands has necessarily been far from exhaustive. Mention of many firms has had to be omitted altogether either

because their goods are too well known to need comment, or because we have described their special products on recent occasions. The "Willing Worker" portable paraffin engines, arranged for concrete mixing, pumping, sawing wood, or electric lighting, shown by Messrs. Drummond Brothers, Limited, of Guilford, is a case in point. The trailing crane of Messrs. Ransome and Rapier, of Ipswich, which can be quickly attached to an ordinary electric truck, was also fully described and illustrated in our columns recently. The automatic telephones system of the Relay Automatic Telephone Company, Limited, of Marconi House, Strand, London, which enables any person to get into communication with any other, without the nuisance of calling up an exchange operator to make the connection, is also well known to our readers, as are the ingenious hand-operated tools for shearing, punching, &c., made by the Tangent Tool Engineering Company, Limited, Keynsham, Somerset.

THE BRITISH ASSOCIATION.

SECTION G.—ENGINEERING.

BEGINNING our comments on the sectional transactions with Section G., Engineering, of which Sir Henry Fowler, K.B.E., is president, we have first to notice the joint discussion of Sections A, B, G, on "Cohesion and Molecular Forces."

COHESION AND MOLECULAR FORCES.

The discussion was held on Thursday, September 13, at 10 a.m., in the Chemical Lecture Theatre, Professor F. G. Donnan, F.R.S., president of Section B, Chemistry, taking the chair. The room was unpleasantly crowded, almost to strain the cohesion of its walls. Section G. had allowed the full morning for the discussion, but the other two sections had put other papers on the agenda, so that the discussion had to be limited to 2 hours.

In opening the discussion, Sir William Bragg, F.R.S., said that the forces that bound atom to atom and molecule to molecule were of fundamental importance to investigations in all branches of science. But the atoms and molecules were so small that experiment could only deal with aggregates of atomic forces. Every stress was built up of innumerable forces differing generally in type, magnitude and direction. In some reactions and in some changes of state the forces might be sufficiently uniform to allow of our drawing conclusions as to the laws governing the single atom; in the phenomena of capillarity which used in particular to be considered as evidence of the action of cohesive forces, the confusion was considerable, and in ordinary experiments with rigid bodies it was complete. To simplify, we considered atoms and molecules as centres of forces exerted in all directions, subject, if electrical or gravitational, to the inverse square law, in other cases the other laws; surface tension and gathering of a liquid into drops had been accounted for in such ways.

The study of radioactivity and X-rays had enabled us to handle the individual atom. Thus we had learnt that there were very strong forces between atom and atom and between molecule and molecule, and that they were limited to very small ranges, small even possibly by comparison with the distances between the centres of the atoms in a crystal. In non-polar compounds, in which separate molecules could be distinguished readily, the alignment was so perfect that we believed the adjustment to have been made in order to bring together certain points on one molecule and certain points on another. The electrostatic attraction between two charged spheres was not an analogous case; we should rather think of two members of a girder adjusted until the rivets could be dropped into their places.

The action of one molecule on another depended upon the relative orientation. In organic compounds the arrangement was generally complicated, but regular and symmetrical as in the girder structure of a bridge. The influence of each molecule did not extend beyond its neighbours; but the action resembled that of the links of a chain. The thickness of the ultimate flakes of some fatty acids, which represented monomolecular films, increased with the number of carbon links in the chain; any link added to either end did not affect the atoms in the middle of the chain. The same linking was observed in the carbon atom itself. In a bismuth crystal the atom was attached to its three neighbours on the one side by bonds which differed from those attaching it to its neighbours on the other side. The monomolecular chain grew by the side-to-side attachment of the molecules; the forces binding layer to layer were feebler than the forces binding the atoms. The cleavage plane of a crystal cut across the weakest bonds.

Several kinds of these bonding forces might be distinguished. When two atoms shared electrons in a compound—how, we do not know—they were strongly bonded. When molecules were bound together in a crystal, or the atoms of sulphur were held together, the bonds were weaker; yet the structure of a metal like aluminium might be likened to that of a polar crystal of rock salt, the sodium atoms corresponding to aluminium, and the chlorine atoms to electrons; though that was certainly not the whole truth. Thirdly, there were the pure electrostatic central actions manifested when the atoms had, by the addition or subtraction of electrons, become similar to atoms of the inert gases; in that case there was attraction all round, and not merely local attraction between a positive charge and the negative charges, and *vice versa*, and calculations of these forces had been made with some success by Born and Landé and by J. J. Thomson.

For every molecule, Sir William continued, there was some most satisfactory way of attachment. In what way this arrangement would come about in the formation of a crystal from a liquid or a gaseous medium was a matter of time and environment. The different rates of growth of different faces of crystals showed that attachment was made more readily at some points of a molecule than at others, and the same consideration applied to colloidal particles, the formation of which Sir William ascribed to irregular or incomplete action. Colloidal gold was crystalline in bulk; it was only the surface of the colloidal particle, therefore, that had gone wrong. The new molecule might receive a shock before it had settled or might not find a suitable place to fit into, an ion might make a spot positive or negative, and cumulative errors might render the surface more and more imperfect. When we wished to simplify the problem, however, we had to work back to the single unit, to take the perfect, single crystal, and to study special conditions, for instance, cleavage planes of weakest attraction.

Dr. W. Rosenhain, F.R.S., who followed on behalf of the metallurgists, said that he would deal with monatomic bodies, the metals and their alloys, which formed simpler types of compounds than organic molecules, in which, however, the phenomena of cohesion, development of strength and ductility, were most pronounced. By the aid of X-ray analysis confirming the result of manifold metallurgical researches, it had become possible to formulate a foundation for a general theory of the nature of alloys. The first principle was that a binary alloy was of the nature of a "solid solution," and consisted of the atoms of the two metals built up on a single space-lattice, the atoms of the solute simply taking the places of atoms of the solvent, and the lattice remaining essentially that of the solvent metal. There was, however, a certain amount of distortion wherever a "stranger" atom was present, and this distortion was responsible for the properties of the material relating to hardness, strength, melting and freezing, and in many other respects. The second principle might be termed the "law of the limiting parameter" or interatomic distance across which the force responsible for interatomic cohesion could appreciably act. That distance was strictly limited. If increased by thermal or mechanical stress or by the introduction of stranger atoms, there would be a limit where the lattice broke down somewhat suddenly, with the formation of another phase which might be a liquid or a different lattice. Heating an alloy simply produced melting; straining caused a break down of the elastic limit; when the limit of solubility of another metal was reached in alloying, crystals of a new type were formed, and for the nature of the "cohesion-bonds" uniting the atoms in such crystals, this interatomic distance was of great importance.

Intracrystalline slip complicated these phenomena in many metals. The stressed crystal underwent plastic deformation by a process of slip along certain planes; the atoms which were attached to each other across those surfaces of slip must be separated, yet there was not complete separation as in actual fracture, but a rapid exchange of partners. Continuity of "bonding" was not lost, though the atoms were torn from their crystalline arrangement and left in a condition of irregular bonding. These phenomena were confined to metals crystallising in the two most symmetrical systems, in which alone the distribution of atoms was sufficiently uniform to allow of a "passing-on" of bonds without complete loss of continuity. For that reason intermetallic compounds (as distinct from solid solutions), as well as crystals of salt and also of antimony and bismuth, were brittle and not ductile; the two metals had, however, uniform atomic distribution on certain planes and showed some ductility when suitably strained. The mechanism of diffusion, Dr. Rosenhain suggested, was that of a movement or slip of atoms in rows, which need not extend throughout even a single crystal. No great amount of stress was required to produce slip at the relatively high temperatures at which diffusion was rapid, whilst brittle crystals showed little, if any, diffusion, except quite near their melting points. On this analogy a "stranger" atom should diffuse the more rapidly, the greater the local distortion it produced in the lattice, whilst a very similar atom should diffuse very slowly; that held for nickel and copper, which diffused much more slowly than zinc and copper, and the radioactive isotope of lead did not diffuse at all into the non-active lead of a nearly identical space lattice, because no lattice distortion occurred, and no stress was set up to move the rows of atoms. That showed that diffusion was not of a kinetic character.

The consideration of the limiting parameter was useful also in arriving at a picture of the inner structure of an amorphous solid or congealed liquid. When a liquid—supposed to be monatomic for simplicity—cooled down, the atoms approached one another within the limiting interatomic range, and adhesions were formed. Under favourable conditions the adhesions became grouped into a crystal lattice. In other circumstances the atoms simply formed irregular groups (increasing in size as the temperature fell) of less close packing than in crystals. The viscosity of such large groups would be greater than that of truly-molten monatomic liquids and would rise with falling temperature, until the whole mass appeared bonded together. Some atoms would be bonded to many neighbours, others to few, and if stress were applied there would be no plastic deformation by slip, since there was no slip mechanism, but three types or stages of deformation were possible. Firstly, there would be purely elastic slip. But some atoms, held to their neighbours at distances just below the limits, would break away when stretched, though that might take time, and extra stress would be thrown on the neighbours; that would be the visco-elastic behaviour of vitreous materials. With still greater stress, some, or all the bonds of some atoms would be broken, and a new equilibrium would be reached, the existing strains being relieved. That would be truly viscous flow which was known also in vitreous bodies, but differed from the viscous flow of true liquids, because it required a definite amount of stress for its initiation.

The nature of an amorphous or vitreous solid was of interest with regard to the cohesion of solid metals in which we had to consider the cohesion within the crystal and the cohesion of one crystal to another. Two atomic lattices, growing towards one another, might adhere to one another in three ways. Certain atoms might be common to both the lattices; the number of these atoms would probably be very small and the junction should, therefore, be weak, but we knew it to be strong, since metals actually broke through the crystals, not along their junctions. Secondly, a zone of intermediate orientation might be formed by the one lattice gradually bending over into the orientation of the other; the principle of the limiting parameter would prevent that. Thirdly, the gap between two adjacent lattices might be bridged over by a region of the irregular atoms of amorphous material. This third view was supported by some experi-

mental facts. Thus whilst a wire made of a crystal aggregate displayed a behaviour under stress which required the presence of some viscous or visco-elastic material, a wire made of a single crystal was free from such phenomena.

The "cohesion bonding" suggested was characteristic of solid solutions, and in these the interatomic distances, although varying by a few per cent., were roughly constant. But in intermetallic compounds we observed greatly reduced interatomic distances. Thus in aluminium itself the distance from centre to centre was 4·3 Angström units; in the copper alloy $CuAl_2$ the distance between the aluminium centres was reduced to 2·4 units, *i.e.*, to two-thirds its value. That probably constituted the real difference between a compound and a solid solution; in the compound the nature of the interatomic bonding was different, and this bonding was possible perhaps only under the influence of some atoms of a different kind whose juxtaposition admitted of a rearrangement of the atomic electron-shells.

Dr. A. A. Griffiths of Farnborough, then spoke on behalf of the engineers; we reproduce his contribution to the discussion on page 377 of this issue.

Sir Ernest Rutherford, called upon by the chairman, said that he could not claim any special knowledge of the problems of cohesion to which the Association had paid serious attention during the past fifty years. He saw great promise in the studies of single crystals by Mr. G. T. Taylor and others.

Professor Ehrenfest, of Leiden, next called upon, referred to the recent experiments of Joffe in Russia, who found that he could electrolytically force ions through crystal slabs of quartz, more easily in the direction of the optical axis than at right angles to that axis, but only as long as the ions (of alkali and other metals) were not too large. Sir Oliver Lodge, then rising, put the profound cohesion problem tersely by remarking that the question was really this: "I pick up one end of a stick; why does the whole stick come up?"

Professor F. A. Lindemann, F.R.S., of Oxford, the next speaker, took exception to the assumption apparently made by Sir W. Bragg and Dr. Rosenhain that atoms were either bonded together or not-bonded, ruling out intermediate conditions such as the old-fashioned fields of force. Fairly definite evidence for intermolecular attraction without definite bonds could be found in the Sutherland correction to the temperature coefficient of the viscosity of gases. The constant involved represented the work done in separating the molecules from contact to infinity, and the relation of this constant to the latent heat of evaporation could not be the statistical effect of occasional bonding. The very high tensile strengths that Dr. Griffiths had obtained, had interested Dr. Lindemann because he had, in previous rough estimates, arrived at the conclusion that the ultimate tensile strength of metals should be between 30 and 100 times greater than observed values. If, in the diagram Fig. 1, the

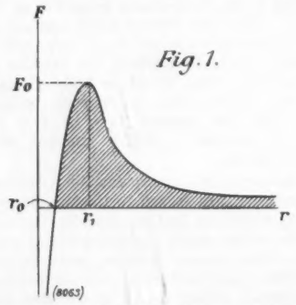


Fig. 1.

abscissa r represented the distance between the atoms, and the ordinate F the attractive force, the tensile strength would give a curve somewhat as indicated. In the unstressed state corresponding to the value r_0, F was zero. When r was greater than r_0, F was greater than zero and there was attraction; with r smaller than r_0, there would be repulsion. The angle $d\,F/d\,r$ was a measure of the compressibility, and the shaded surface a measure of the latent heat of evaporation. The maximum force F would correspond to the tensile strength and r to the maximum extension; if F and r could be measured, a great deal of information would be gained; but even at the temperature of liquid hydrogen the observed tensile strength was far too small to fit in with the known latent heat and compressibility. We were measuring the strength of a yarn of wool, not of single fibres, which might give much higher values as Dr. Griffiths had shown. The simple law of force which he, Dr. Lindemann, had assumed could only hold approximately; but he was convinced that atoms acted upon one another at finite distances and did not remain free until snapped into position.

Professor R. W. Wood, of Baltimore, mentioned a peculiar, so far unexplained, experiment due to a Japanese physicist. A thin plate of rock salt, that would not bend, could be bent immediately after being dipped into hot water; neither warm water nor oil would do. Dr. L. F. Richardson subsequently suggested that the surface layers of the bent rock salt became strained, but were dissolved away by the hot water.

Sir Henry Fowler contented himself with pointing out the urgent need of a fundamental investigation of the cohesion problems; the engineer had occasionally unpleasant surprises even when working in accordance with the most approved experience.

Professor W. L. Bragg (son of Sir William), of Manchester, referring to Dr. Rosenhain's remarks on the reduction in the distance between the aluminium atoms in the compound $CuAl_2$, pointed out that there must be a critical point at which the repulsive force between the atoms would set in, and he would have expected that the violent distortion of the crystals in uniting would result in twinning.

Professor E. N. da C. Andrade, remarked that all metals were capable of flow, but their flow was not that of viscous fluids. The rate of metallic flow under a given stress was not constant at the beginning, though it became so, as he had shown; secondly, with different stresses the final rate was not a linear function of the stress. The departures from viscous flow were due to the crystalline structure of metals. But the higher the temperature, the more the two types of flow approached one another. If true flow could be obtained that would probably mean that under the given stress all the flow was taking place in the amorphous material. Such flow recent experiments by himself and Mr. J. W. Lewis showed, was possible near the melting-point, and it was interesting that sodium, some 60 deg. C. below its melting-point, was far softer than tin, a few degrees below its own melting-point. The coefficient of viscosity of the amorphous metal was probably connected with the number of the outer electrons of the metal atom. Professor P. Langevin, of Paris, dwelt upon the importance of electro-magnetic forces—in addition to electric forces, which alone could not yield a steady equilibrium—and of the quantum relations in these problems.

Professor F. C. Lea finally pointed out that, so far as the engineer was concerned, little progress had been made on broad theoretical lines. There were discontinuities in atoms, molecules and crystals; engineers had to deal with aggregates of crystals, often badly treated, and they wanted guidance as to the conditions of failures for such aggregates. The ultimate strength was not all-important; engineers were concerned with the ranges of stress that would cause failures after repetitions. These stress ranges did not accord with other ranges, cold work and hot work affected different properties in different ways.

In briefly replying, Sir William insisted that research had to start with the simplest problem, but admitted that the term "bond" might convey an erroneous meaning. Dr. Rosenhain said that the strength curve would fall off more rapidly than Dr. Lindemann's curve. The twinning at the boundaries, about which Professor Bragg had inquired, might be ultra-microscopic; but it had never been observed in aluminium. With regard to the flow of metals it was noteworthy that all movement took place in the crystal boundaries, and not in the crystals.

Vocational Tests for Engineering Trades.

In the afternoon the Engineering Section met with Section J (Psychology) for a joint discussion on the question of vocational tests in the engineering trades. The president of Section J, Dr. C. Burt, after welcoming the members of the Engineering Section, called upon Mr. M. H. Tagg to read a communication introducing the subject. Mr. Tagg first called attention to the importance of using proper methods for selecting employees and for guiding juveniles in the choice of a career. The object of the discussion, he said, was to consider vocational tests in their relation to both selection and guidance. It was possible to devise four or five tests occupying some 15 minutes or 20 minutes which would serve to indicate whether or not a man was suitable for some particular job, although other factors had to be taken into account in vocational testing. These were general intelligence, specific abilities, temperamental disposition and physical fitness. He then proceeded to outline some investigations made to determine the part played by these factors in the engineering trades for the purpose of formulating tests for various occupations, such as pattern-making, fitting, turning, tool-making and drafting.

With regard to general intelligence the speaker thought that this was required to a greater extent in engineering than in other industries, and he added that there was an upper as well as a lower limit to the degree of general intelligence required; a man might be too intelligent for his particular job. In determining the special abilities required in the various trades, investigations had been carried out firstly by an engineer performing all the operations himself in order to arrive at some conclusion as to the abilities most necessary for the work, and secondly by a psychologist observing a workman carrying out the operations. These might be described, respectively, as the internal and external methods of investigation. Altogether some 60 tests were carried out in this way on groups of youths in engineering schools. The conclusions arrived at, however, were that the stock laboratory tests were of too artificial a character to be of much use in vocational selection, and also that group tests were only useful as a rough guide, individual tests being desirable for final selection. In individual tests, he remarked, the investigator came into personal contact with the candidate, and was thus able to see the method of attack adopted by him and also to judge something of his temperamental disposition. Observation in these matters, he added, was of no less importance to psychologists than mathematical analysis.

The conclusions to be drawn from the investigations referred to were that tests could be formulated which would have a high correlation with trade ability and could be used in vocational selection; that such tests were tests of the special abilities required in the various trades; and also that there is some central factor common to the trades considered. He meant by the last-mentioned conclusion that several different special abilities would be required for all branches of any trade, but that the relative importance of any one of these abilities would vary with the grade of work to be carried out. In conclusion, he remarked that the problem now under consideration was to weigh these abilities according to the particular class of work required.

The next communication taken was one by Messrs. A. P. M. Fleming and H. J. Brocklehurst, which was read by the latter. In the course of this paper the authors expressed the view that the only field left for the study of selection by psychological tests was in relation to juvenile workers, particularly apprentices to the skilled trades. The general method adopted by psychologists was to determine separately the factors considered to be essential to successful work in a given trade, and then to devise tests for the detection and measurement of those qualities. In general, the test of the suitability of a candidate to carry out a particular kind of work was the performance of the actual work, this obvious procedure being commonly applied in industry and forming the *raison d'être* of the usual probationary period. Psychological analysis, in the case of an engineering craft, could never take account of all the factors which influenced the performance of an individual. Special attention was drawn to the effect of home influence in awakening the interest of a youth in some particular trade, and the writers' experience indicated that a boy's success was largely determined by his original and sustained interest in

his trade. The three essentials to success in an engineering trade were general intelligence, physical fitness and interest, and psychological tests would be of great help in measuring the first of these. Physical fitness could easily be determined by a medical examination, but the measurement of interest was a difficult problem. A period of probation was the most effective method of determining a boy's interest in, and suitability for, apprenticeship to an engineering trade.

In a third communication by Mr. J. G. Taylor, the author pointed out that the difficulty of selecting apprentices was greater than that of selecting workmen, since in the case of apprentices the employer had not only to choose a type of youth likely to turn out generally satisfactory but also to decide which trade he should be apprenticed to. The selection was usually made either as a result of an inspection of the boy's school records, by a personal interview, or on the results of an entrance examination. The first-mentioned method, the author said, was not really reliable, although it was of more value when all the apprentices were drawn from the same technical school. The method of interviewing candidates had the advantage of being easy to apply, but had the drawback that it was not possible in this way to measure the candidates' vocational aptitude; it was useful, however, in conjunction with a written examination. The speaker expressed the opinion that an arithmetic paper was a good test of intelligence, but added that intelligence tests should be conducted so that they were not tests of knowledge, owing to the varying opportunities that candidates might have had of acquiring this.

The chairman then declared the matter open for general discussion. The first speaker, Mr. J. J. McKie, said his experience indicated that engineering apprentices were usually superior in intelligence to youths destined for less-skilled trades and referred to the use of a definite schedule of questions at interviews. This speaker was followed by Sir Henry Fowler, the President of the Engineering Section, who first referred to the wide scope for co-operation between psychologists and engineers in the matter under discussion. With regard to Mr. Taylor's contribution to the discussion, the speaker was not in agreement in the matter of personal interviews, which he regarded as the best form of vocational test. Nervousness of candidates, however, was a difficulty both in interviews and in written examinations. Continued interest of a worker in his trade, the speaker agreed, was a matter of great importance, but the monotonous character of some of the work introduced a difficulty with some types of men.

Professor F. C. Lea, the next speaker, said he thought the results of examinations and intelligence tests must depend on the innate intelligence of the subject, on his environment in school and home life, and also on the examiner. Engineers, he added, would welcome a test to select the right men for a particular vocation, and it was also extremely important to the individual himself that he should adopt a suitable trade. He thought it would be best to select boys during their educational period, as the test should extend over a longer period than an interview or an examination. Industry, he concluded, must look to the educational system, for the selection of suitable workers.

The next speaker, Professor T. H. Pear, agreed with Sir Henry Fowler that interviews might be very useful and important, but remarked that they were tests of the interviewer as well as of the candidate. The characteristics required in the latter varied greatly with the nature of the work he would have to carry out, and this should be carefully considered by the interviewer. He thought the latter might learn much by studying the manner in which medical examinations were carried out. Professor Sir J. B. Henderson referred to the system employed in the selection of naval officers. He did not think that an arithmetic paper was a very satisfactory test for future engineers, remarking that brilliant mathematicians might do well in arithmetic as schoolboys, but did not usually make good engineers. Born engineers, he thought, could be picked out most satisfactorily during a period of probation. Professor F. G. Bailey also, thought a period of probation essential, and agreed with the last speaker that an arithmetical test was of little use in selecting engineering apprentices.

Dr. G. H. Miles, who followed, said the object of industrial psychologists was to reduce the probationary period as far as possible, adding that if a good system of vocational selection could be devised much time and labour would be saved. Vocational tests, at present, were admittedly imperfect, but he thought that, in time, such tests would meet the requirements of engineers. Mr. L. Urwick gave the results of vocational tests made in the United States and referred to the importance to engineers of early interest in mechanical matters. He remarked that if this early interest foreshadowed ability it should be possible to detect it by comparatively short tests. Mr. J. S. Wilson, the last speaker in the discussion, inquired whether different interviewers arrived at the same conclusion with regard to any particular candidate.

The chairman then called upon the authors of the three introductory papers to reply to the points raised by the speakers in the discussion. Mr. Taylor, who replied first, said he thought Sir Henry Fowler's criticisms had been answered by several of the other speakers, and expressed general agreement with Professor Lea's remarks as to the desirability of co-operation between engineering concerns and schools in the selection of apprentices. To Mr. Wilson's query he replied that in interviews carried out by eight different persons in a group of candidates the results were found to vary from 65 per cent. to 80 per cent. of the possible total for the whole group, and in the case of a single candidate examined by two different interviewers the marks allotted were 60 per cent. and 70 per cent., respectively. Mr. Brocklehurst, who then replied, said he thought most of the speakers had confirmed the fundamental point he wished to make, viz., that interest in his work was the criterion of a man's success. Some speakers had expressed the view that the probationary period was uneconomical, but at present there was no better alternative. He was sorry if his paper had suggested that the results obtained from vocational tests were less satisfactory than had been anticipated, since he actually felt that there was an enormous field of utility for psychologists in the selection of juveniles for employment in engineering works. In his reply, Mr. Tagg agreed with the speaker who had remarked that if engineering ability were inborn and not acquired it was possible to formulate tests to discover it. He also referred to the importance of distinguishing the difference between direct and indirect interest of candidates in any particular calling, and added that interest was largely dependent upon environment. Few men, he continued, were competent to act as interviewers, and vocational tests might well be applied to them. With regard to the selection of employees from the results obtained during a probationary period, the speaker cited the case of a large concern which found it necessary to engage four times the number of workers actually required in order to make a selection in this way, which was obviously a very costly procedure. Vocational tests would be much less costly, and as they had proved to be profitable both in the United States and Germany, he thought British engineers would find them equally so.

This concluded the proceedings, as far as the Engineering Section was concerned, and the meeting was then adjourned.

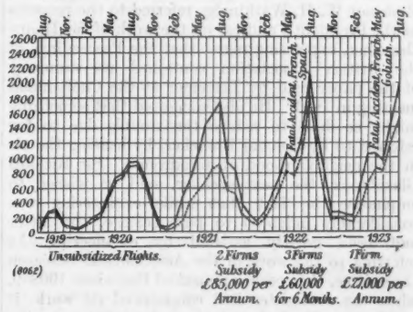
TRANSPORT PROBLEMS.

On the morning of Friday, the 14th inst., the members assembled to hear the presidential address delivered by Sir Henry Fowler, K.B.E. This address, which we reprint in full on page 377 of this issue, was entitled "Transport and Its Indebtedness to Science." and before reading it Sir Henry expressed his thanks to the Association for having elected him president of the section. At the conclusion of the address a vote of thanks, moved by Professor F. C. Lea, was carried with acclamation, and the President, after acknowledging the vote, explained that the remainder of the morning would be devoted to a discussion on transport problems, on which four separate papers had been prepared. These papers were then read in succession by their respective authors and were afterwards discussed together.

The first paper read was one by Mr. A. E. Berriman, dealing with "Road Transport," and this was followed by a paper by Colonel E. O'Brien, entitled "The Future of Transportation by Rail." These two papers are reprinted in full on pages 380 and 381, respectively, of this issue, so that we need not deal here with the nature of their contents. The third communication was by Major General Sir Sefton Brancker, and this dealt with the question of air transport. General Brancker said he proposed to divide his remarks into four sections, dealing with the value of air transport, what had been accomplished by it up to date, its weak points, and, with the assistance rendered by science in its development. He thought it unnecessary to say much about the value of air transport, which was sufficiently obvious, and in dealing with the progress made he referred to the diagram reproduced below. This diagram, he pointed out, related only to traffic on the London-Paris air route and clearly showed the effect of subsidies on development. The

Fig. 2.

TRAFFIC ON LONDON-PARIS ROUTE.



seasonal effects on the traffic were quite evident as also were the effects of two fatal accidents. Although these accidents had both occurred to French machines they had each been followed by a reduction in the number of passengers carried by both French and British lines. It would also be seen that from 1919 till the end of 1920, British lines had carried practically the whole of the traffic, but by August, 1921, the French lines had secured about half the total. Since that time, however, we had improved our position, and we now carried about 80 per cent. of the traffic. The author also mentioned that, in the year ended March, 1923, 11,460 passengers and 216·4 tons of cargo had been carried on all the British air lines, and that from April to August of this year, 9,800 passengers had been carried. Since April, 1922, he said, no fatal accident to a paying passenger had occurred on the regular British air lines, although the machine mileage flown since then amounted to about 1,500,000.

Those figures proved, he thought, that air transport could be operated safely and reliably. The cross-Channel services, however, were merely experimental; they would become true business propositions when extended farther. With regard to the cost of aerial transport, the author stated that with comparatively heavy traffic, in which 2,250,000 miles would be flown per annum, the rate per ton mile would be 3*s.* 6*d.*, of which 49 per cent. would be accounted for by standing charges and 51 per cent. by flying costs. With light and fluctuating traffic, in which 1,000,000 miles were flown per annum, the corresponding figures would be 5*s.* per ton-mile, 64·35 per cent. standing charges and 35·65 per cent. flying costs. It was important to notice how the cost decreased as the mileage flown increased.

The basic factor with regard to cost, he said, was the quantity of paying load carried per horse-power. For the machines in use, the paying load was from 3·8 lb. to 4 lb. per horse-power, but a machine was now available in which 5 lb. or 6 lb. of paying load could be carried per horse-power. The weak points of air transport were bad visibility and high cost, and these they were trying to reduce. For bad visibility he thought wireless apparatus would be the best antidote. The pilot could be

warned of bad landing conditions by wireless and could also be informed of his true position. For flying in clouds a completely stable aeroplane was necessary, and that, the speaker said, was coming. Engine improvements would give increased reliability and the use of heavy fuel oil would reduce fuel costs; other directions in which improvement might be anticipated were in connection with geared engines, variable propellers, slotted wings, &c., which would enable a machine to get off the ground with a heavier load than at present. The use of metal construction would lower costs and decrease structural weights, and he looked to science to assist in the development of aviation in these and in other directions. He concluded with a few words on the possible developments of airship transport, calling attention to the fact that the journey to the Far East might well be made *via* the Polar regions, the weather conditions in which were very suitable for airship travel.

After a few brief remarks by Professor Sir Ernest Rutherford, who was present, the chairman called on Mr. A. T. Wall to read his paper on "Sea Transport," but as this is reprinted in full on page 382 of this issue we may now proceed to deal with the discussion on the four papers. The first speaker, Professor W. H. Watkinson, referred to the remarks in the President's address on the work of Sir Henry Bessemer, expressing regret that the Proceedings of the British Association contained no summary of the paper read by Bessemer at the Cheltenham meeting in 1856. He also suggested that something might be done to reduce the trouble due to fog referred to by General Brancker, by heating the air in the neighbourhood of aerodromes. Sir Richard Glazebrook, the next speaker, said he wished to emphasise the fact that while engineering was considerably indebted to pure science, the latter had been greatly assisted by engineering. In referring to the work of the Aeronautical Research Committee, the speaker remarked that since 1908–9, when the committee had commenced its work, it had been realised that advance depended upon the solution of a number of elaborate problems, which could only be solved by the application of pure science. Considerable progress had been made, but the work was expensive, and he appealed for further support on the financial side. The United States, he added, was forging ahead in aeronautical research, and unless we could advance more rapidly than at present (for which more money was needed) we should not be able to retain the premier position we had held in this direction.

The discussion was continued by Professor T. Hudson Beare, who said he wished to supplement Professor Watkinson's remarks on Bessemer's British Association paper by pointing out that the meeting took no notice of it, and it was not discussed at all; no one then realised that the process described in the paper would revolutionise the world. The speaker also expressed the opinion that the railways of the country afforded a wide field for improvements, and suggested that the necessary works should be carried out as soon as possible in order to relieve unemployment. Alderman Bennett referred in appreciative terms to General Brancker's paper and expressed surprise that aviation had not made more rapid strides. He thought this might be partly due to the fact that the risks of aviation were greatly exaggerated in the newspapers, so that the public became unduly nervous.

The discussion then turned largely upon the question of the elimination of fog by artificial means, Professor G. Stoney remarking, in this connection, that from a rough calculation he had made he found it would require about 1,000 tons of coal to raise the temperature of 1 cub. mile of air by 10 deg. F. as had been suggested by Professor Watkinson. He thought a more promising method would be the electrical process of depositing dust and fumes due to Sir O. Lodge. Professor Watkinson here stated that he had not meant to heat the air by combustion, but by means of the Kelvin warming machine, which he thought would be preferable to the electrical process. Sir Richard Glazebrook, however, maintained that figures obtained by Sir Napier Shaw and other meteorologists tended to support those given by Professor Stoney, and added that all artificial methods of dispelling fog so far suggested seemed to be quite out of the question. Dr. J. S. Owens, continuing the discussion on this point, said another aspect of the fog question was its prevention, as distinguished from its dispersion, which he agreed was impracticable. Fog production, he pointed out, was not only a question of temperature and condensation; hygroscopic nuclei in the air played an important part in the process, and if these could be eliminated the amount of fog formed would be reduced. The products of combustion, particularly sulphurous and sulphuric acid, were an important source of the hygroscopic nuclei, and these could be reduced. He wished to refer to the importance of studying atmospheric pollution from the point of view of visibility, which was one of the essential considerations in connection with transport. Smoke fogs he concluded were preventable, and water fogs were partially preventable.

Referring to Mr. Berriman's paper, Professor Stoney asked his opinion of gas producers for road vehicles. The speaker thought that producers had a great future in this application, since coal was the most important fuel in this country. Professor Sir J. B. Henderson, who spoke on General Brancker's paper, said he was disappointed to find that General Brancker pinned his faith to wireless direction finding for navigation purposes. The speaker thought that means would be found for measuring ground speed accurately, and if this were done and a gyroscope were employed, it would be possible to navigate by dead reckoning; gyroscopes, he added, might also be employed in connection with the automatic control of the steering apparatus of aircraft.

The only other speaker in the discussion, Professor F. C. Lea, also referred to General Brancker's paper, dealing particularly with the supercharging of engines and high altitude flying. He thought this problem was largely bound up with the development of the gas turbine, which in turn was dependent upon the production of suitable materials. No steel at present available was suitable for the purpose, but it was possible that a light alloy, other than steel, might be found to work satisfactorily at a temperature of 800 deg. C. To provide for the large airships of the future, the speaker continued, it would be necessary to carry on organised research on metals for light construction, and also to investigate the best forms of sections and methods of connection. Light alloys, at present, were not satisfactory, and he thought success might be achieved with some improved form of steel.

At the conclusion of Professor Lea's remarks, the chairman called upon the authors to reply, and Mr. Wall, who spoke first, said he only wished to emphasise what Professor Lea had said on the subject of materials, and to express regret that the question of transport on canals had not been dealt with at the meeting. General Brancker who followed, said Mr. Wall had asked in his paper whether large skimming liners would be possible. The speaker replied that he thought they would be. At present the size of aircraft was limited by the size of engines, the largest of which could develop 1,000 h.p. Three such engines might be employed on a single machine, but the development of very large machines for use on land was limited by the weight which could be carried by the wheels running on the soft ground of an aerodrome. There was no such limitation in the case of the flying boat, and he understood that large machines of this type could be made relatively lighter than small ones. In connection with fog dispersion he mentioned that large quantities of cordite had been burnt on the coast of France at Entretât, and it had been noticed that the heat produced had had the effect of clearing the air of mist and fog for some considerable time. He thought, however, that any method of heating the air would be too expensive to be practicable. In reply to Professor Sir J. B. Henderson, the speaker said he did not propose to depend entirely upon wireless methods of navigation, but such means would be quite suitable for flights in short stages. For Transatlantic, or other long flights, different navigational methods would be necessary. With regard to the question of high altitude flying, he thought it would be found quite possible in the future to fly to America at an altitude of 30,000 ft., or 40,000 ft., and to perform the journey at speeds of the order of 250 m.p.h. to 300 m.p.h.

Colonel O'Brien, who then replied, referring to the difficulty of flying in a fog, said he thought some instrument of the gravitation type might be developed which would indicate the presence of obstacles, and also inquired of Mr. Berriman whether the possibilities of using pulverised fuel in internal-combustion engines had been considered in connection with road transport. Mr. Berriman replied that this was out of the question as far as he could see, and in answer to Professor Stoney's query as to the use of gas producers on road vehicles, stated that, as far as weight and bulk were concerned, the position of the gas-propelled vehicle was about equal to that of the steam wagon. The disadvantage of the former was that it required a more carefully selected fuel than the steam wagon. There might also be some difficulty in connection with the carbon monoxide emitted by gas-propelled vehicles under certain conditions of working.

This completed the business of the meeting, but in adjourning it, the chairman expressed surprise that Professor Hudson Beare had not noticed what the railways were already doing to effect improvements. The matter, he added, was constantly before them, and always must be. He then thanked the authors of the papers collectively and the meeting terminated. In the afternoon the members visited Messrs. Cammell Laird's shipyard at Birkenhead.

(To be continued.)

INDUSTRIAL NOTES.

SOME few years ago certain trade unions started an additional workman's college as a rival to the Ruskin College at Oxford. The reason appeared to be that by mixing with other students at Oxford, there was a danger of the workmen students getting to know too much to be docile followers of Karl Marx. Probably those responsible for this movement will do their best to discourage the arrangements which, as Mr. N. Chamberlain announced on Saturday, are being made at Birmingham University, by which students nominated by local trade unions will be enabled to take certain courses at the University and be thus enabled to grasp at any rate the fundamental laws which govern the natural world, to trace the development of our state of society, to learn something of the history of their country and of its relations with other countries, to acquire some knowledge of literature, which had so profoundly interested the thoughts and actions of men and women in the past, and to train their minds for clear and concise expression. It is felt that it may be possible to offer, to a limited number of those who have the keenness and the enthusiasm to desire such an opportunity, some instruction of this general character, supplemented perhaps by instruction in economics and commercial history, without taking them away from the occupations in which they may be engaged.

Economic studies at Oxford show little sign of recovery from the Ruskinite doctrine that a compassionate nature forms an adequate equipment for the discussion of industrial and economic problems. Thus at a meeting held at Balliol College last Saturday, certain speakers animadverted on the "soul-killing" Ford system by means of which men are secured a high standard of living, and leisure for the pursuit of their hobbies or of culture studies. A Miss Matthias, for example, asserted that we did not want men of intelligence if we were going to "Fordise industry." The essential fact, however, is that the ordinary skilled man differs from the exceptional craftsman just as an ordinary educated man differs from an exceptional one. The ordinary skilled man is best employed where possible in repetition work which, on the Ford system, secures him a good livelihood and ample leisure, just as the ordinary educated man had better be engaged in routine work rather than in attempting to make a living by futile contributions to literature, science or art. Most of the work of the world is hodman's work, and the majority of the population are fitted for little else, and do not resent it; and, indeed, in many cases even prefer it. It is an advantage therefore to make such work as little onerous and as remunerative as possible, and this is the essence of the Ford system. There is still room for men of courage, insight and initiative in carrying out the quantitatively inferior, but intrinsically much more important tasks which are beyond the powers of the average man.

The Chief Registrar of Friendly Societies states that membership of registered trade unions declined during the year from nearly 7,000,000 to little more than 5,500,000, and funds were reduced by about 5,000,000*l.*

These reductions were attributable to severe trade depression, which cost registered trade unions nearly 7,500,000*l.* in unemployment pay beyond the amount recovered from the Ministry of Labour under the State insurance scheme. The expenditure of so great an amount in one year on unemployment pay has no parallel in trade union history. But for the savings effected during war years and additional levies, it would have absorbed the whole of the accumulated funds. The equally abnormal expenditure of 3,500,000*l.* upon dispute pay was mainly due to the coal-mining dispute. In spite of the heavy strain placed on the finances of the unions, the accumulation of funds during war years enabled them to carry forward at the end of the year a larger balance of funds than they ever had before the war. The number of trade unions registered during the year was 37, and 72 were removed from the register. Nineteen unions were dissolved, and 10 were removed from the register by cancelling. The number of amalgamations during the year was large, and 43 unions were removed from the register owing to this cause, as compared with 19 in the previous year.

A joint meeting of the Mining Association and of the Miners' Federation has been arranged for Friday, October 4, in order to discuss the amendments to the National Wage Agreement formulated by the Miners' Federation at their meeting at Folkestone last July. These include a demand for a readjustment of the percentages in which the income of the industry, after meeting other charges, is divided between wages and profits. The present division of the income is in the proportion of 100*l.* in wages to 17*l.* in profits on the income required to meet the standard wages, and 83*l.* in wages to 17*l.* in profits for the division of the balance of income.

In addition, an increase is asked for in the present minimum wage equivalent to the rise in the cost of living since 1914. The present minimum wage varies from 20 per cent. to 30 per cent. above the 1914 wages. The present cost of living is 70 points above the 1914 figures. Since July 1 about 800,000 of the men employed in the industry have been earning wages which are equal to, or higher, than the increase in the cost of living when compared with the 1914 wages. Some 300,000 men are working in districts where the wages paid remain on the minimum. The Federation also seek more detailed information with respect to charges other than wages which are given in the monthly ascertainments.

These three proposals were submitted to the coal-owners at a meeting with the Mining Association on August 2, when Mr. Evan Williams stated that the issues involved were of so vital a character that the opinion of the general body of coalowners would have to be ascertained before a reply could be given.

According to *The Ministry of Labour Gazette* the decline in employment which began in July continued in August. Among workpeople insured the percentage unemployed was 11·5 at August 27, compared with 11·3 at July 23, and with 11 at June 25. At the end of August, 1922, the corresponding percentage was 12·3. The total number of workpeople registered at the Employment Exchanges as unemployed at August 27 was approximately 1,266,000, of whom 943,000 were men, 237,000 were women, the remainder being boys and girls. At July 30 the total was 1,235,000, of whom 936,000 were men and 223,000 were women. The percentage of unemployed among members of trade unions from which returns are received was 11·4 at the end of August, compared with 11·1 at the end of July.

Changes in rates of wages reported as having taken effect in August resulted in an increase of nearly 24,000*l.* in the weekly full-time wages of nearly 250,000 workpeople, and in a reduction of about 14,000*l.* in the wages of over 180,000 workpeople. The increase occurred mainly in the iron and steel trades, as the result of recent increases in selling prices, and as regards the tin-plate workers in South Wales and Monmouthshire, and hosiery workers in the Midlands. The decrease affected tramway workers, furniture trade operatives in London and Manchester, men employed in flour mills, and iron ore miners in Cumberland. These were in accordance with adjustments made by changes in the cost of living.

Since the beginning of 1923 the changes in rates of wages reported to the department have resulted in a net reduction of over 500,000*l.* in the wages of over 3,200,000 workpeople and a net increase of over 290,000*l.* in the wages of nearly 1,200,000 workpeople. Trade disputes involving stoppages of work reported to the department as beginning in August numbered 45. In addition, 28 disputes which began before August were still in progress at the beginning of the month. The total number of workpeople involved in all disputes in August was approximately 68,000, as compared with 95,000 in the previous month and 31,000 in August, 1922. The estimated aggregate duration of all disputes during August was about 1,200,000 working days, as compared with 1,665,000 days in July, 1923, and 312,000 days in August, 1922.

The annual report of the Boilermakers' Society for the year 1922 shows that the membership at the end of December was 94,739. This is 6,195 less than twelve months previously. The report states further that the union was originally known as the Friendly Boilermakers' Society, and a large expenditure is in fact incurred in friendly benefits. Last year the society paid 53,461*l.* to sick members; 12,934*l.* in death claims; 57,428*l.*, a record sum, to superannuated members, and 187,789*l.* in unemployment benefit. The depression in trade was unparalleled in the history of the union, yet in spite of the heavy disbursements there was a credit balance of 400,000*l.* at the end of the year. The sum is large, but in view of the callous way in which the members of this union profiteered during the war, it is perhaps hardly surprising. Mr. John Hill, the secretary, suggests that the unemployment benefit is a mistake, as he asserts that it helps to maintain a surplus of labour and thus supplies manufacturers with their strongest weapon in reducing wages and lowering conditions of employment. This characteristic utterance would seem to indicate that Mr. Hill is still a convinced Marxist in spite of the complete rebuttal of that writer's views by the course of the Russian revolution. Mr. Hill's theories are more completely put forward in the commentary published in the monthly journal of the society, where he asserts that slumps in trade are brought about entirely by financial manipulations, and seems to imagine that an Argentine farmer, or a Brazilian railway, is prepared to pay any price for an agricultural engine or a locomotive that British builders choose to demand. He is unable to see that the effect of high prices is to restrict demand, and elsewhere asserts that the milling industry should be carried on at annual loss if the alternative is a higher price for flour. Fortunately, these absurd beliefs are not universal amongst our craftsmen, many of whom have more sense of fair play, and a greater insight into economic questions than some of their leaders.

Speaking at Southport on Tuesday last, Mr. J. T. Brownlie said that he estimated the capital value of a skilled engineer of 23 years of age as in the region of 10,000*l.*, and deprecated the loss to the country ensuent on the emigration of such men to America. It would be interesting to know the basis of Mr. Brownlie's estimate. The census of production taken in 1906 showed that material which passed through the engineering shops of the country had in the average its value increased at the rate of 109*l.* per annum per man employed. Of this total the workman received on the average over 80*l.* and the remainder was spent on design, management, power, lighting, rates, taxes, selling expenses, and dividends.

On this basis the capital value of the average skilled man would be nearer 2,000*l.* than 10,000*l.*, though of course exceptional craftsmen exist, whose value is very far above the average.

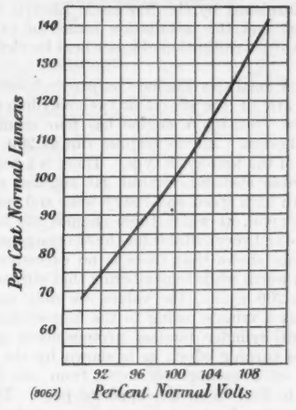
THE RELATION BETWEEN CANDLE POWER AND VOLTAGE OF GAS-FILLED LAMPS.

IT is generally known that the superior efficiency of gas-filled incandescent electric lamps as compared with ordinary drawn wire lamps lies in the higher temperature at which it is possible to maintain the filament. This temperature effect is very considerable, and a reduction of 1 per cent. in temperature reduces the light produced by 11 per cent. Against this consideration has to be set the fact that the life of the lamp is increased as the temperature is reduced, and it has been estimated that if a present-day 100-watt gas-filled lamp were operated at the efficiency of the electric incandescent lamps of the 'eighties it would, independent of course from accidental breakage, have a life of 47,000 years. It is the practice of incandescent lamp makers to rate their lamps to have an average life of 1,000 hours, and it is interesting to consider the economic effect of running lamps at a lower voltage than that at which they are rated in order to prolong their useful life.

Some figures and curves relating to this matter have been furnished to us by the British Thomson-Houston Company, of 15, Savoy-street, London, W.C. 2, in an article by Mr. W. Millner. The change in light output of a gas-filled lamp is not proportional to the change in voltage, but varies in accordance with the curve given in the annexed figure from which it will be seen that a 10 per cent. reduction in applied voltage reduces the light output by 32 per cent. Owing to the temperature coefficient of tungsten, the reduction of current through the lamp is not proportional to the reduction in voltage, but varies according to a curve connecting percentage normal amperes with percentage normal volts, which has the equation $A = 0{\cdot}6\,V + 40$, where A is percentage normal ampere and V percentage normal volts. This condition makes a lamp to some extent self-regulating on fluctuating voltage. The corresponding curve connecting percentage normal watts with percentage normal volts has the form $W = 1{\cdot}6\,V - 60$, where W is the percentage normal watts.

A 100-watt, 100-volt gas-filled lamp has a light output of 1,300 lumens, and is listed by the makers at 5*s.* For the 1,000 hours normal life of this lamp the cost of the energy consumed at 6*d.* a unit is 50*s.*, so that the total cost of supplying 1,300 lumens for 1,000 hours is 55*s.* This figure excludes attendance, interest on wiring, &c., but covers all the items which are concerned in a consideration of the effect of running the lamp at a lower voltage. If the lamp is operated at

LUMEN CHARACTERISTIC OF TUNGSTEN FILAMENTS.



(8067)

10 per cent. below the normal voltage it will be seen from the curve that the light output will be reduced to 68 per cent. of the normal, so that only 885 lumens will be given. The equation $W = 1{\cdot}6\,V - 60$ shows that if V is reduced to 90 per cent. of normal, the watts will fall to 84 per cent. of normal, so that the cost of supplying 885 lumens for 1,000 hours will be 42*s.* The increase in the life of the lamp owing to the reduction in voltage by 10 per cent. cannot be stated quite definitely, but it may be assumed that the life will be doubled, so that the cost of renewal will fall from 5*s.* to 2*s.* 6*d.*, and the total cost of 885 lumens for 1,000 hours will be 44*s.* 6*d.* At this rate the cost of the 1,300 lumens for 1,000 hours, which the original arrangement gave, will work out at 65*s.* 3*d.* as compared with the original 55*s.*, so that a loss of 10*s.* 3*d.* is sustained in obtaining 1,300 lumens for 1,000 hours if the lamp is run at 10 per cent. below its rated voltage. A smaller loss will be sustained the lower the cost of energy; but it may safely be said that in no normal case will it pay to use lamps at a lower voltage than that for which they are designed.

TESTS OF THE ZENITH CARBURETTOR.—We have received from the Zenith Carburettor Company, Limited, of 40, Newman-street, London, W. 1, diagrams recording the results of experiments upon their carburettor. These show that no petrol is delivered by the main jet at speeds below 5 m.p.h., the compensating jet supplying the whole of the fuel up to that point. From 10 m.p.h. to 35 m.p.h. the delivery of the compensating jet remains nearly constant, while the delivery of the main jet increases steadily with the speed of the car. Below 16 m.p.h. the greater part of the fuel is supplied through the compensating jet, while at 40 m.p.h. the main jet supplies about 78 per cent. of the total.

OVERSEAS VISITORS TO THE SHIPPING AND MACHINERY EXHIBITION.—The promoters of the Shipping, Engineering and Machinery Exhibition now being held at Olympia entertained a large number of distinguished visitors from Overseas to dinner on September 13, in the dining hall attached to the exhibition building. The guests were received by Sir Charles A. Parsons, the honorary president of the Exhibition Committee, and Mr. F. W. Bridges, the organising manager. Among the speakers at the dinner were Lord Aberconway and Sir J. Fortescue Flannery, Bart., M.P., who dealt with the "World's Shipping and Engineering Industries." Dr. H. S. Hele-Shaw, chairman of the committee of experts, proposed the health of the guests, for whom response was made by Mr. Herbert, of New York, who spoke of the advantages of international co-operation in matters of standardisation and trade. Mr. A. H. Ashbolt, the Agent-General for Tasmania, in proposing the "Success of the Exhibition," dwelt strongly on the desirability of fostering inter-Imperial trade, pointing out that every emigrant was a potential producer of foodstuffs and raw material and a consumer of manufactured products.

THE GAS ENGINE POWER STATION OF PALMERS' SHIPBUILDING AND IRON COMPANY.

(*Continued from page* 292.)

As already stated, the electric generating plant at this station is driven by eight vertical tandem gas engines built by the National Gas Engine Company, Limited, of Ashton-under-Lyne. Seven of the engines are each of 1,500 b.h.p., and are direct coupled to 1,000-kw. 6,000-volt three-phase alternators made by the English Electric Company. The eighth engine is of 1,000 b.h.p., and is direct coupled to a 700 kw. 240-volt direct current generator made by Messrs. Bruce Peebles and Co. The three-phase sets run in parallel with the public supply furnished by the Newcastle Electric Supply Company, and the installation forms an excellent example of the utilisation of waste heat for electricity supply.

The National Gas Engine Company's 1,500 b.h.p. engines are of the six-crank twelve-cylinder type, while the 1,000-b.h.p. engine has four cranks and eight cylinders. All the engines run at 200 r.p.m., and are of the four-cycle type. There is a tendency to associate enclosed vertical gas engines of this class with high speed and heavy wear and tear, but the 200 r.p.m. at which these engines run is quite moderate and very suitable for the electric generators. Experience shows that there is no excessive wear, and it is worth while remembering that although the speed is 200 r.p.m., the valves are only operated 100 times a minute owing to the four-stroke cycle. The multi-cylinder tandem arrangements gives a very fine turning effort, as is shown by the reproduction of a tachograph curve from one of the engines in Fig. 25 on the opposite page. The fine curve is not only due to every down-stroke of the connecting rods being a driving stroke, but also to the cushioning effect obtained in the closed space between the top piston and the cover of the bottom cylinder. As every up-stroke is also a compression stroke the reciprocating parts are well cushioned. The piston speed is 800 ft. per minute, which is very moderate for this type of engine.

The engines are housed in the same power station as the gas-blowing engines. The station is a steel building, 245 ft. long by 100 ft. wide, which is served by an overhead electric travelling crane, and is well lighted. A plan of the electric generating end of the engine room is given in Fig. 20, annexed, from which it will be seen that no space is wasted, while the general view of the station given in Fig. 31 on page 368, shows that ample working room has been left between the various engines. A comparison may be made between Fig. 20, showing the lay-out of the plant, and the corresponding Fig. 15 which appeared on page 290 of our issue of September 7th, which also shows the lay-out of the gas-blowing plant driven by horizontal engines. As may be expected the comparison well illustrates the greater horse-power per unit of floor area which is obtained with the vertical tandem engines, but the comparison is more favourable to these engines than it might be in some other cases owing to the large amount of space taken up by the blowing engines of the horizontal sets as compared with the electric generators of the vertical sets. The total brake-horse-power of the horizontal sets is 6,600, and they occupy an engine room space of 135 ft. by 101 ft. or an area of 2·06 sq. ft. per B.H.P. installed. The total brake-horse-power of the vertical engines is 11,500, and they occupy a space 106 ft. by 101 ft. or 0·93 sq. ft. per B.H.P. installed.

In describing the details of the National gas engines we may confine ourselves to the larger size, as the smaller 1,000 b.h.p. engine differs in no important particular except its smaller number of cylinders. The engines are built on a system of standard units, and the cylinder diameters, connecting rod and valve dimensions of the two sizes of engine are identical, so that the major part of the spares which are carried at the station are available for either size of engine indifferently. This matter is of considerable importance in an installation of the size of that with which we are concerned in which there are eight engines having in all 46 connecting rods, 92 inlet valves, &c. All parts are standardised to a fine limit, and when pistons have to be cleaned the spare line can be used and the engine put into service, the line taken out being cleaned and becoming the spare, for future operation. The time required for changing a line piston, &c., and replacing with the spare parts is a matter only of 4 hours to 6 hours, depending on the labour available.

One of the 1,500-b.h.p. engines is illustrated by longitudinal and cross sections, and by end elevation in Figs. 21 to 23, on Plate XXI. The tandem cylinders are clearly shown in section in Figs. 21 and 22, while an independent view of the arrangement is given in Fig. 24, on page 365. Each cylinder is a separate casting, the bottom cylinder being bolted direct to the top of the crank-case, and the top cylinder on to the upper end of the bottom cylinder. The cover over the bottom cylinder makes a joint on the small ledge formed owing to the top cylinder being slightly larger in diameter than the bottom cylinder. The space between the bottom cylinder cover, or "middle head" and the top piston is permanently closed and forms a buffer cylinder in which compression takes place during the down-stroke and expansion during the up-stroke, thus cushioning the reciprocating parts during the down stroke and relieving the pressure on the crank-pin during the up-stroke. As the top and bottom cylinders fire alternately, both on the four-stroke cycle system, every up-stroke is also cushioned due to the compression in either one or other cylinder, and the result is that very smooth running with practically no wear on the pins is obtained. The tachograph curve from one of these engines reproduced in Fig. 25 has already been referred to. This was obtained with a Dr. Horn's tachograph and shows that the cyclic irregularity is exceedingly small, approximating to 0·01 per cent. The theoretical turning effort curves are reproduced in Fig. 26.

As can best be seen in Fig. 22, each cylinder casting is of an inverted "L" shape, the valves being carried in the horizontal arm of the "L." In order that valves of one cylinder shall not interfere with those of another these horizontal arms are staggered, so that the valves of the top cylinder do not come directly above those of the lower. This can clearly be seen in Fig. 21. The inlet and exhaust valves are placed one directly above the other, the exhaust valve at the bottom being operated directly by a push rod. The inlet valves are carried in self-contained cages and are worked by rocking levers which are operated from the camshaft by push rods. A sketch of the arrangement is given in Fig. 27, on page 365, while the actual details of the valves and rods are well shown in Fig. 21. The arrangement makes all valves easily accessible. Each cylinder barrel and combustion chamber is made of comparatively soft iron to allow of distortion due to unequal expansion during working, and a liner of hard iron providing a good wearing surface for the piston. As will be seen from the figures the pistons are not water-cooled, the cylinder jacket cooling arrangement having proved over many years working to be effective in keeping the pistons at a reasonable working temperature, even when rich gas is used. As will be seen from the figures, the water jacket is cast in one piece with the cylinder barrel, but is attached to it at the top only so that the barrel is free to expand independently of the jacket. The bottom end of the water space is closed by a ring made in halves and fitted with a gland.

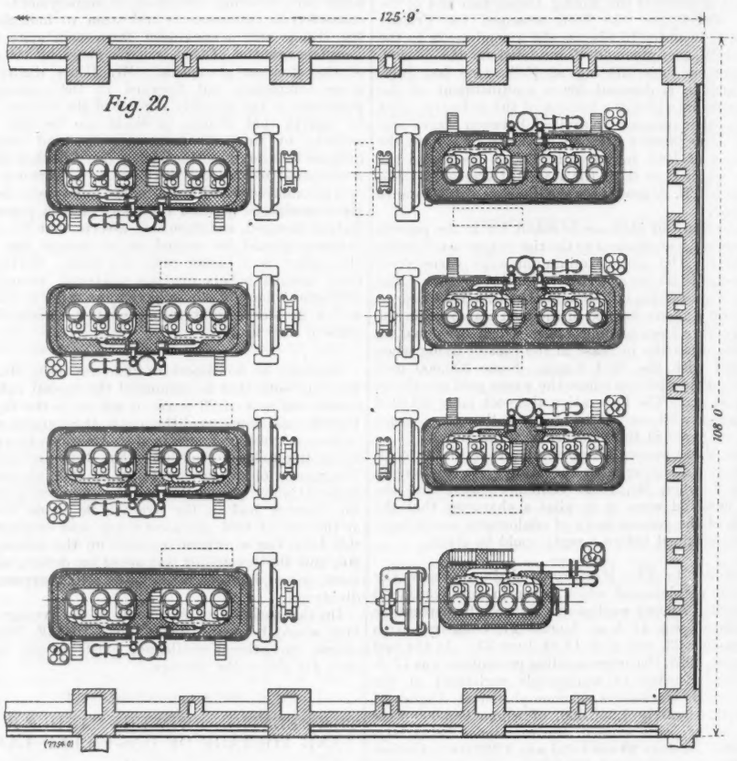


Fig. 20.

The lower pistons are of the trunk type, fitted with unusually large case-hardened gudgeon pins, and are connected to the upper pistons by a chrome-nickel steel bolt passing through a cast-iron sleeve which acts as a distance piece. The sleeve is ground true in a lathe along with the pistons after assembly. The sleeve works in a metallic-packed gland in the middle head. The packing consists of a series of cast-iron rings bearing on the cast-iron sleeve. With a normal amount of lubrication the arrangement is found to work well, and it is the usual experience that after a year's continuous running no shoulder is formed on the rod. The line consisting of top and bottom pistons, piston sleeve, middle head and connecting rod can be withdrawn for inspection or cleaning by removing the top cover and pole screws securing the middle head. The whole is lifted through the top cylinder by the overhead crane by fixing a clip to the top piston. The diametrical clearance between the piston and cylinder is greater than is usually allowed in vertical gas or oil engines, as the tandem arrangement considerably reduces the tilting effort of the piston due to the friction between the piston pin and connecting rod. As will be seen from Figs. 22 and 23

the cylinders are set *desaxé* to relieve the side thrust of the piston on the cylinder walls. Ramsbottom piston rings are fitted.

The general arrangement of the engine is well shown in the figures on Plate XXI, and the general view given in Fig. 32, on page 368. It is of the enclosed pattern and made in two units, each of six cylinders. The two-piece bedplate is made so that the joint between the two parts does not come on the centre line of the engine. This is clearly shown in Fig. 21. The joint in the upper half of the crank-case comes, however, on the centre line so that there is a fair distance between the two joints, and the bed plate and crank case when bolted up make practically a continuous girder about 7 ft. deep. A series of ribbed arches is carried between the front and back plates of the crank-case, and a very stiff connection provided between the seat for the cylinders and the main bearings. The crankshaft is made in halves bolted together by a flanged coupling and there is one round-backed bearing between each pair of cranks, one at each end and one on each side of the coupling. Any bearing may be taken out for examination without lifting the crankshaft. The camshaft is made in two independent parts, which are not connected. It runs in bearings mounted in the crank-case casting and is held in position by long set screws from the top of the crank-case. Each part of the camshaft is driven separately by means of a single helical geared wheel directly from the crankshaft. This arrangement which is shown in Figs. 21 and 23 is remarkably simple as compared with the double skew gear or bevel drive with a vertical shaft which is usually adopted in large internal-combustion engines.

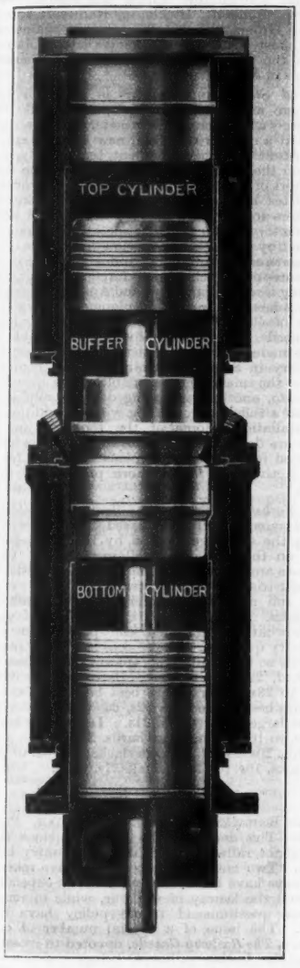


FIG. 24.

Fig. 25. TACHOGRAPH CURVE.

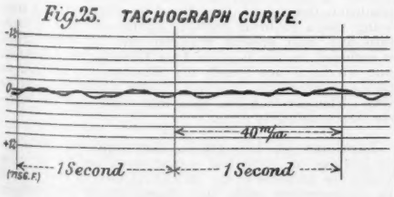
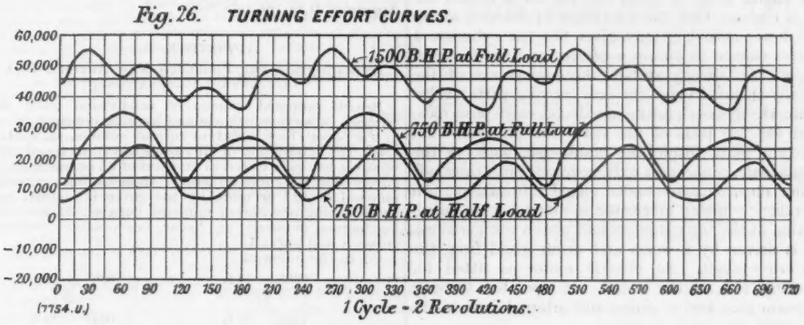
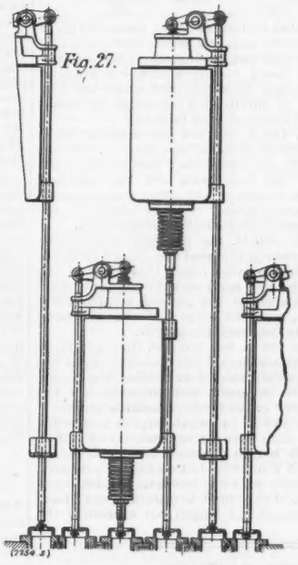


Fig. 26. TURNING EFFORT CURVES.





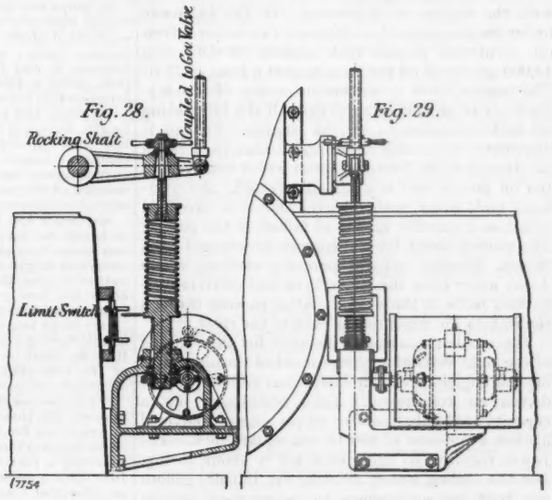
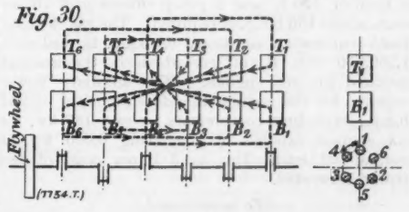


Fig. 30.



The original five six-crank engines which were supplied by the National Gas Engine Company for Messrs. Palmer's power station were fitted with the makers' standard flywheel, which is illustrated in Figs. 21 to 23. Owing, however, to resonance between the periodic impulses in the mechanism of the engine and the natural phase-swing of the alternator it was decided to change the flywheels. The new wheels are 12 ft. in diameter, and at the normal engine speed of 200 r.p.m., have a peripheral speed of 7,500 ft. per minute, which is somewhat higher than usual practice. The flywheels of the last two engines installed were only 9 ft. 9 in. in diameter. The flywheel is forced on to the end of the crankshaft and acts as a half-coupling for the electric generator which is of the single bearing type. Although this is not the usual practice with internal-combustion engines it has been the standard practice of the National Gas Engine Company for all their vertical engines, and has given every satisfaction.

The governing of the engine is effected by two throttle valves which control the quantities of gaseous mixture supplied to the cylinders, the gas and air being kept separate right up to the inlet valves. The governor, which can be seen in Fig. 23, is mounted on a horizontal shaft driven from the crankshaft by helical gear wheels. An independent emergency governor is also fitted which cuts off the gas supply in case of overspeed. The seven engines driving alternators are provided with specia speed gear which can be operated by hand or by electric motor controlled from the switchboard. By means of this gear the speed of the engine can be adjusted 7 per cent. above or below the normal. The gear which is connected up to the governor valve is illustrated in Figs. 28 and 29, subjoined. As will be seen a limit switch is fitted to break the motor circuit in case of attempted overwinding of the gear.

Duplicate ignition is arranged throughout the engine, there being two high-tension sparking plugs in each cylinder. It is found that there is practically no loss of power if one of these plugs is out of commission. Current is obtained from four six-cylinder magnetos made by the British Lighting and Ignition Company. The magnetos generate low tension current which is converted to high-tension in coils. A change-over switch is fitted so that battery ignition can be used in connection with the make and break and distributor on the magneto, but practice has shown that the battery ignition is used only to a very limited extent. The magnetos are mounted on and driven from a gear-box containing a central spur wheel which is mounted on the end of a horizontal shaft driven by bevel gears from one of the camshafts. The arrangement can be seen in cross-section in Fig. 23, and is indicated by broken lines at the centre of Fig. 21. A diagram showing the order of firing of the cylinders is given in Fig. 30, annexed. The timing of the magnetos can be adjusted to suit each cylinder independently or all

cylinders simultaneously, while the engine is running if required. Rubber-covered cables encased in tinned brass tubes carry the current to the sparking plugs. The cable terminals are provided with vulcanite handles, and the strength of the spark can be ascertained at any time while the engine is running.

The engines are started by compressed air stored under a pressure of from 300 lb. to 350 lb. per square inch, and admitted to the bottom cylinders only. The timing valves, which are driven from the camshafts, automatically cease operating as soon as the engine is up to speed and the air is turned off. It is claimed that the admission of starting air to the lower cylinders only gives the top cylinders a better chance to obtain a correct mixture for good firing. As already stated, the engines are of the totally-enclosed type, the only moving parts visible being the flywheel, inlet and exhaust valve push rods, and the top ends of the valve rod plungers. All moving parts inside the crank-case, such as the crankshaft, connecting rods, governor pins, camshaft roller pins, &c., are under forced lubrication. An ordinary cylinder lubricator is fitted for the lubrication of the top cylinders and piston rod packings. It is driven by a worm and worm wheel from the governor shaft. An electric motor is fitted for turning the engine round. It operates through a worm gear and a pinion and internal rack in the flywheel.

The oil circulating system fitted in connection with the engines is of interest. In the basement under the gas engine floor there are two motor-driven oil circulating pumps, each capable of delivering 10,000 gallons of oil per hour against a head of 72 ft. The motors have a continuous rating of 7 b.h.p. Each set is capable of supplying all the lubricating oil under pressure to all the engines. The oil is distributed by a ring main, and drains back to an oil strainer in the basement from which it travels to the oil pumps and is again distributed. An overhead tank fitted with oil-level alarms is provided to act as a standby in case of failure of the pumps. The cooling water for the engines is obtained from Messrs. Palmers' general pumping station, which draws water from the River Tyne and delivers it to various parts of the works. After passing through the jackets the water drains back to the river.

The auxiliaries actually installed for the running of the eight vertical engines consist of the oil pumps, one gas engine-driven air compressor and one motor-driven air compressor. Each compressor has a capacity of 60 cub. ft. of free air per minute, delivered against a pressure of 350 lb. per square inch. The power required to drive each set is about 25 h.p. For the cooling water, allowing for 180,000 gallons per hour for six engines to be pumped against a head of 120 ft. and a pump efficiency of 70 per cent., about 156 b.h.p. is required. The gas cleaning plant requires an additional 95 b.h.p. to deal with 1,350,000 cub. ft. of gas which is the amount required for six engines. The auxiliary power required for the engines therefore amounts to 251 b.h.p., excluding compressors, or say, 187 kw. for six engines capable of generating 6,000 kw. at normal full load. This is 3·1 per cent. of the power generated.

(To be continued.)

TRADE LECTURES AT THE CITY OF LONDON COLLEGE.—A course of 20 lectures on iron and steel will be delivered at the City of London College during the ensuing session, by Mr. B. Kelly, member of the Iron and Steel Institute. The first lecture will be delivered on Tuesday, September 25, at 6 p.m. The fee for the whole course is 20*s.* for residents in the County of London and the County of Middlesex, but a higher fee will be demanded from students residing outside this area. Particulars can be obtained on application to the College, White-street, Moorfields, E.C. 2.

AUSTRALIAN TRADE.—His Majesty's Senior Trade Commissioner in Australia, Mr. S. W. B. McGregor, in his report to the Department of Overseas Trade, shows that the imports for the year ending June 30, 1923, were 131,808,673*l.*, an increase over the figures for the previous year of 28,742,237*l.* The exports, however, showed a decrease of nearly 10,000,000*l.*, and there was an adverse balance of trade amounting to 13,895,590*l.* The total value of the imports of metal and machinery was 35,195,931*l.*, an increase of over 10,000,000*l.* The greatest percentage changes were shown in steel rails (417), wire (173), motor car chassis (110), and in plates and sheet metal (70).

THE WATERTIGHT SUBDIVISION OF PASSENGER SHIPS.

IN submitting his paper on "Notes on the Curves and Formulæ for Regulating the Watertight Subdivision of Passenger Ships" to the Institution of Naval Architects, at the Summer Meeting in Holland, Sir Archibald Denny, Bart., stated that some modification was necessary in Appendix B (see ENGINEERING, current volume, pages 316 and 317), in view of the changes suggested by the Informal Committee. These we made general reference to in our article on the meeting in the same issue (page 307), but now that the altered wording of the proposals is available we reprint Appendix B in the new form.

APPENDIX B.

EXTRACT FROM THE PROPOSED NEW ARTICLE VIII CONVENTION REGULATIONS.

British proposed scheme of subdivision using the criterion of service formulæ and limiting numerals given in the paper (ENGINEERING, current volume, page 315).

(*a*) The subdivision of all vessels 430 ft. in length and upwards having a criterion numeral of 23 or less shall be governed by the curve A factors; those having a criterion numeral of 123 or more by the curve C factors, and those having a criterion numeral between 23 and 123, by factors obtained by linear interpolation between curve A and curve C.

(*b*) In the following :—

$$S_1 = \frac{9382 - 20\,L}{34} \qquad S_2 = \frac{8267 - 20\,L}{29}$$

$$S_3 = \frac{7152 - 20\,L}{24} \qquad S_4 = \frac{6037 - 20\,L}{19}$$

(i) Ships less than 430 ft. but not less than 260 ft. in length having a criterion numeral equal to S_1 shall be subdivided abaft the fore peak using the factor of subdivision unity; and those having a criterion numeral between S_1 and 123 shall be subdivided abaft the fore peak using a factor of subdivision obtained by linear interpolation between unity and the factor C.

(ii) Ships less than 430 ft. but not less than 235 ft. in length, having a criterion numeral less than S_1, but not less than S_2, shall be so subdivided that neither the combined length of the fore peak and the adjacent compartment, nor the length of any other compartment forward of the machinery space, nor the length of the aftermost compartment exceeds the floodable length.

(iii) Ships less than 380 ft. but not less than 210 ft. in length having a criterion numeral less than S_2 but not less than S_3, shall be so subdivided that neither the combined length of the fore peak and the adjacent compartment, nor the length of the second compartment abaft the fore peak, nor the length of the aftermost compartment, exceeds the floodable length.

(iv) Ships less than 330 ft. but not less than 185 ft. in length, having a criterion numeral less than S_3 but not less than S_4, shall be so subdivided that neither the length of the fore peak, the adjacent compartment nor the aftermost compartment exceeds the floodable length.

(v) Ships less than 280 ft. in length having a criterion numeral less than S_4 shall have a fore peak not exceeding in length the floodable length obtained directly from the cross curves (Plate XXV in 1912–15 Committee's Report) assuming a permeability of 100 per cent., nor less than 10 ft. plus 5 per cent. of the ship's length, and shall have an aftermost compartment of length not exceeding the floodable length.

STEEL CASTINGS.

TO THE EDITOR OF ENGINEERING.

SIR,—I should be glad to know why the deliveries of steel castings are so bad in our country. It seems to me to be a very serious matter and a general complaint amongst engineers that there is so much delay. I have tried many firms of steel makers, and the usual time quoted is three to four weeks, and the delivery is usually from six weeks upwards. At the moment, in spite of a quotation of from three to four weeks, my firm have been waiting nine weeks for some castings. I believe it would be of great interest if some of your readers would explain to us of the uninitiated why we never get deliveries in three to four weeks? It seems a pity that quick deliveries cannot be made when trade is so slack.

Yours faithfully,
H. A. PERTWEE, M.I.Mech.E.

"DIESEL-ELECTRIC" SHIPS.—The La Playa, the first to be completed of three electrically-propelled vessels which are being built by Messrs. Cammell Laird and Co., Birkenhead, for the United Fruit Company, of Boston, Mass., has carried out successful official trials on the Clyde. Specially-built for the carriage of bananas in tropical zones, she is 325 ft. long, and has a sea speed of 14 knots. Her propelling power is in four generating units, each of which consists of a four-cylinder "Cammell-aird-Fullagar" Diesel engine running at 250 r.p.m., directly coupled to a generator supplying continuous current for propulsion purposes at 220 volts. The main generators are electrically coupled in series, and although all four are in operation at full power, three, two, or one may be used at reduced powers if desired. The adoption of four main generating sets ensures very economical operation at reduced powers. The electrical propelling equipment has been supplied by the British-Thomson Houston Company, Rugby, and the wiring, switchboard and auxiliary motors by the Sunderland Forge Company.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Hull Coal Traffic.—A still further expansion in South Yorkshire exports is shown in the official returns relating to traffic *via* Hull for last month. The total quantity received during August, 564,317 tons, represented an increase of 10,595 tons on the receipts of August, 1922. This brought the total receipts for the first eight months of this year up to 4,715,900 tons, as compared with 3,217,922 tons for the corresponding period of last year. Again Germany was the largest export buyer, the total tonnage sent to that country during the eight months of this year having exceeded 1,250,000 tons. The second largest buyer was France, other prominent customers being Sweden, Belgium and South America. The largest contributors during the month were the Brodsworth, Bullcroft, Hickleton, Ramcroft and Yorkshire Main Group with 104,927 tons, as against 95,000 tons in August, 1922. Denaby and Cadeby Main came second in the list with 46,033 tons, as compared with 40,645 tons in August last year.

Iron and Steel.—Improvement is far from general, though here and there favoured sections are working beyond pre-war capacity. Contracts, however, continue to expire at a quicker rate than new business is booked, with the result that unemployment, temporarily, at least, is again on the increase, and in Sheffield alone does not fall far short of 30,000. The latest shading of quotations in hematites has brought a few more inquiries from steel-makers locally, but has not resulted in anything like satisfactory bookings. The special steel branches are severely hit by continued depression despite the increased requirements of the automobile industry, while in certain manufactures of high-class steels foreign tariff impositions are proving a severe handicap, and American competition is a serious factor. Current development is largely along the lines of electrical and electrification requirements, railway needs, and mining expansion. Notable strides are being made locally in connection with the last-named. One colliery in South Yorkshire has just completed a plant for the manufacture of bleaching powder and caustic soda, another is putting down a sulphuric acid plant, and a third is proceeding with an additional coke oven installation. Some of the tool and implement branches are doing better. Substantial orders have just been placed for mining implements and tools for South Africa. Activity is rather more pronounced in drills and files.

South Yorkshire Coal Trade.—Business is rather more active all round now that increased supplies are available following the stoppage created by the St. Leger week. Exports on the whole are well maintained. Germany and France are taking big tonnages of best hards, though home industrial requirements show but little expansion. Cobbles and nuts are steadier under the influence of export sales. The increased consumption of gas coke has somewhat strengthened the position in furnace and foundry qualities. House coal is steadily improving with prices so far unaltered. Quotations :—Best branch handpicked, 29*s.* 6*d.* to 31*s*; Barnsley best Silkstone, 26*s.* 6*d.* to 28*s.*; Derbyshire best brights, 25*s.* to 27*s.*; Derbyshire best house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire best large nuts, 20*s.* to 21*s.*; Derbyshire best small nuts, 15*s.* to 16*s.*; Yorkshire hards, 21*s.* to 23*s.*; Derbyshire hards, 20*s.* to 22*s.*; rough slacks, 11*s.* 6*d.* to 13*s.* 6*d.*; nutty slacks, 10*s* to 12*s.*; smalls, 7*s.* to 9*s.*

"THE RAILWAY GAZETTE"; INDIAN PROGRESS NUMBER.—The developments in India since the war have brought railway affairs in that country into prominence. Two notable investigations have taken place, the railways have been faced with heavy expenditure to make good the leeway of the war, while in some cases important questions of future policy have required solution. The issue of a special number of our contemporary, *The Railway Gazette*, devoted to recent affairs affecting the Indian railways, brings together a large amount of material which is thus of very live interest. In addition to general articles on Indian railway matters, including the proposed grouping, this issue contains articles on the several railways, describing their present condition, developments in hand or proposed, and steps being taken to bring existing equipment and facilities into line with present requirements. A short article is included on the Khyber Pass Railway now building, but we have not found the illustrations referred to. Other illustrations, however, make ample amends for this. The selection has been well made and the reproduction excellently done.

LECTURES ON INDUSTRIAL MANAGEMENT.—A series of lectures on industrial management are to be given under the auspices of the Industrial League and Council in co-operation with the Regent-street Polytechnic. The lectures commence on October 12 with addresses to the students by the Right Hon. G. N. Barnes and Mr. W. L. Hichens. After that the subjects will be confined to expert lecturers, who include Mr. A. W. Kimberley on "The Financial Organisation of Industry"; Mr. A. P. M. Fleming, M.Sc., on "Industrial Research"; Mr. A. R. Stelling, Dipl. Ing., on "Factory Management"; Mr. H. Atkinson, on "The Relative Rewards of Capital, Management and Labour"; Mr. James F. Butterworth, on "Motion and Fatigue Study"; Dr. Edgar L. Collis, on "The Safeguarding of Health in Industry"; Mr. H. W. Allingham, on "The Economic Aspect of Cost Accountancy"; and Mr. F. S. Button, J.P., on "The Attitude of Labour to Problems of Industrial Organisation." The fee for the whole course is 5*s.*, single lectures 1*s.* Tickets can be obtained from the General Secretary, Industrial League and Council, 82, Victoria-street, S.W. 1.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Sales of Cleveland pig-iron continue on only a very moderate scale, but they show some little improvement, and include parcels for Scotland, slightly better supplies for some of the local foundries, and one or two small lots for the Continent. An encouraging feature is a little inquiry on forward account. No. 3 is easier in price, but values of other grades are upheld. Quotations stand:—No. 1 quality, 102*s.* 6*d.*; No. 3 g.m.b., 97*s.*; No. 4 foundry, 92*s.* 6*d.*; and No. 4 forge, 90*s.*—all f.o.t. makers' works, and f.o.b. Tees.

Hematite.—Rather considerable sales of East Coast hematite do not appear to have checked demand for that commodity, and with stocks being slowly but steadily reduced, the situation in the hematite branch is improving. Inquiries are still in the market for supplies to Sheffield, South Wales and Germany, and values show further upward tendency. Nos. 1, 2 and 3 are fully 99*s.*, both for home purposes and for shipment to destinations abroad, and up to 100*s.* is asked.

Foreign Ore.—There is next to nothing doing in foreign ore, transactions being confined to sales of odd cargoes. Prices are still based on 23*s.* c.i.f. Tees for best rubio.

Blast-furnace Coke.—Durham blast-furnace coke, of good average quality, is quoted round about 40*s.* delivered to local consumers.

Manufactured Iron and Steel.—Some little improvement is noticeable in one or two branches of manufactured iron and steel. Substantial sales to Japan are anticipated, and already considerable parcels of sheets have been sold and despatched to that country. Inquiries generally are better, but there is still much competition for orders that come into the market. Common iron bars are quoted 12*l.*; iron rivets, 14*l.*; packing (parallel), 8*l.* 10*s.*; packing (tapered), 11*l.* 10*s.*; steel billets (soft), 9*l.*; steel billets (medium), 10*l.*; steel billets (hard), 10*l.* 5*s.*; steel ship, bridge and tank plates, angles, joists and heavy sections of rails are all put at 9*l.* 10*s.*; fish plates are 12*l.* 10*s.*; and galvanised corrugated sheets (24-in. gauge, in bundles), 19*l.* 5*s.*

INTERNAL-COMBUSTION ENGINES AND SUCTION GAS PLANT.—The National Gas Engine Company, Limited, are willing to loan, free of charge, lantern slides showing various portions of their works, installations, sectional views, &c. A descriptive list of slides will be forwarded on request.

BRITISH PRODUCTION OF PIG-IRON AND STEEL.—The production of pig-iron in August amounted to 599,800 tons, compared with 655,100 tons in July and 411,700 tons in August, 1922; the furnaces in blast at the end of the month numbered 196, a further decrease of 10 during the month. The output of steel ingots and castings amounted to 582,700 tons, compared with 624,300 tons in July and 528,400 tons in August, 1922.

RETIREMENT OF MR. W. W. GRIERSON.—By the courtesy of the Editor of *Modern Transport* we have been favoured with an advance copy of the issue of our contemporary, which will appear to-morrow. This contains the announcement of the forthcoming retirement of Mr. W. W. Grierson, C.B.E., from the position of chief engineer of the Great Western Railway, and includes an excellent portrait of Mr. Grierson. He will relinquish his executive duties with the Great Western Railway, with which he has been connected during the whole of his professional career, at the end of the year, but will continue to act as consulting engineer to the company.

THE INSTITUTE OF TRANSPORT.—The Council of the Institute of Transport has bestowed its triennial gold medal upon Mr. Dixon H. Davies (member) for his paper on "The Finance of the Modern Highway: A Problem and a Solution," and has awarded premiums in respect of the session, 1922–23, as follows: Railway (operating) gold medal to Sir Philip Dawson, M.P., for paper on "The Financial Investigation of the Prospects of Railway Electrification"; railway (engineering) gold medal to Sir Robert Hadfield, D.Sc., F.R.S., for paper on "Modern Trackwork and its Importance"; road transport (passenger) gold medal, to Mr. Sidney E. Garcke (member) for paper on "Passenger Transport by Road in Rural Areas"; aviation gold medal, to Major-General Sir W. Sefton-Brancker, K.C.B. (member), for paper on "Air Transport"; water transport gold medal, to Dr. Bryson Cunningham, D.Sc., for paper on "Cargo Handling at Ports: British and American Methods Compared"; dock and harbour gold medal, to Mr. Alfred H. Roberts (member), for paper on the subject selected by the donor, namely, "The Most Expeditious and Economical Method of Handling Goods at the Quayside"; Institute silver (graduate) medal, to Mr. E. W. Bayliss, for paper on "Tramways—Their Scope and Object, &c."; Institute silver (student) medal, to Mr. H. A. Groome, for paper on "The Science and Significance of Compiling accurate Time-Tables"; "Modern Transport" premium, to Mr. A. Wardle (graduate), for paper on "Historical development of the Railway Goods Rate." These will be presented at the meeting of the Institute to be held in the Lecture Theatre of the Institution of Electrical Engineers, Victoria Embankment, London, W.C., on Monday, October 1, on which occasion Sir Joseph G. Broodbank will be inducted as president for the ensuing year, and will deliver his inaugural address.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—With the demand for almost all kinds of steel material at the very lowest the industry in Scotland cannot be said to be any better this week. Inquiries from overseas are gradually improving, but the amount of business fixed up recently does not represent a very heavy tonnage. The actual state of things now is that every little order is extremely acceptable as it helps to keep the plant in motion and stave off the possibility of a compulsory closing down. Once or twice within recent months several works now running had, on different occasions, very little to go on with. Structural sections are in fair demand, but shipbuilding material is almost dead at present. Black sheet makers are doing tolerably well on light sheets for abroad, and galvanised sheets are also in good request, but the home demand is very poor, particularly for the thicker gauges. Prices continue firm, but buyers cannot be induced to place orders. The following are to-day's quotations:—Boiler plates, 13*l.* per ton; ship plates, 10*l.* per ton; sections, 9*l.* 15*s.* per ton; and sheets, 12*l.* 10*s.* per ton, all delivered Glasgow stations.

Malleable Iron Trade.—No change of any kind falls to be reported in the West of Scotland malleable iron trade, and the state is as last week. Work is being carried on intermittently and there is little life in anything that is doing. The actual demand is slow and inquiry is very limited. Current prices are unchanged with "Crown" bars called 12*l.* per ton, delivered Glasgow stations.

Scottish Pig-Iron Trade.—For weeks past producers have been easing their prices for Scottish pig-iron in the hope of securing more business, but it is very evident that buyers having no immediate outlet are not inclined to enter into commitments. There is little hematite iron going to the steel works and foundry sorts are also in poor demand. The export trade is off to a large extent just now and few lots have been booked of late. Prices are as follows:—Hematite, 5*l.* 5*s.* per ton, delivered at the steel works; foundry iron, No. 1, 5*l.* 5*s.* per ton and No. 3, 5*l.* per ton, both on trucks at makers' yards.

Scottish Pig-Iron Shipments.—The export of Scottish pig-iron from Glasgow Harbour for the week ending last Saturday, September 15, amounted to 2,492 tons. Of that total 2,340 tons went overseas and 152 tons went coastwise. For the corresponding week of last year the figures were 588 tons foreign and 194 tons coastwise, making a total shipment of 782 tons.

Shipbuilding Order.—The Union Steamship Company, of British Columbia, have placed an order for a passenger steamer with the Coaster Construction Company, Montrose, through the owners' agents, Messrs. J. H. Welsford and Co., Liverpool. This new vessel, which is to be finished early next year, will be the largest vessel ever constructed at Montrose. Her dimensions are to be 236 ft. in length overall and 40 ft. in breadth.

THE INSTITUTE OF BRITISH FOUNDRYMEN.—The Lancashire branch of the Institute of British Foundrymen, which has its headquarters at the College of Technology, Manchester, has issued its syllabus for the ensuing session. Copies can be obtained from the Secretary, Mr. T. Makeson, 21, Beresford-road, Stretford, Manchester. The president for the year is Mr. R. A. Miles, of Newton Heath, who will deliver his presidential address on Saturday, October 6, at 4 p.m. The meeting will be held in the College of Technology.

AERONAUTICS AT THE IMPERIAL COLLEGE.—The syllabus of the Department of Aeronautics of the Imperial College of Science and Technology for the coming session covers three sections. They are concerned, respectively, with Design and Engineering, Meteorology and Navigation. The first section includes lectures on Aerodynamics, by Professor Bairstow, the director of the department, on Aircraft Design by Mr. F. T. Hill, and on the Strength of Aircraft Structures by Mr. W. S. Farren. The lecturers on Engine Design are Dr. H. Moss and Mr. W. J. Stern, and the subject of Airships is dealt with by Mr. V. C. Richmond. The section on Meteorology is under the direction of Sir Napier Shaw, while Aerial Navigation is taken by Squadron-Leader H. E. Wimperis. During the session, lectures on special subjects will be given by some of the professors and lecturers of the College, by members of the staff of the Royal Aircraft Establishment, and by others.

THE BRITISH ACETYLENE AND WELDING HANDBOOK.—A new handbook has to be added to the long list of works which are primarily intended to assist industries and facilitate trade. We refer to the new "British Acetylene and Welding Handbook," prepared by a committee of the British Acetylene and Welding Association, and published at 7*s.* 6*d.* by *The Acetylene and Welding Journal*, 30, Red Lion-square, Holborn, W.C. 1. This book brings together in a handy form a great deal of information of value to those engaged in the industry concerned. Here may be found the official orders and regulations relating to acetylene and carbide, transport, and so on. Sections of the volume are devoted to the historical side of the production of acetylene, and to the physical and chemical aspects of the subject. Articles are included on "Dissolved Acetylene," "Oxygen," "Applications of Acetylene," "Oxy-Acetylene Welding and Cutting," &c. It will doubtless assist the development of the industry by putting useful information into the hands of many who have hitherto thought their work unsuited to the processes dealt with. It is good propaganda work.

NOTICES OF MEETINGS.

THE INSTITUTION OF AUTOMOBILE ENGINEERS: NORTH OF ENGLAND CENTRE.—Wednesday, September 26, at 6.30 p.m., at the Milton Hall, 244, Deansgate, Manchester. Opening Informal Meeting, when "Labour-Saving Methods and Devices in Repair Work" will be shown and demonstrated.

THE INSTITUTE OF BRITISH FOUNDRYMEN: LANCASHIRE BRANCH, BURNLEY SECTION.—Wednesday, September 26, at 7.15 p.m., in the Municipal College, Omerod-road, Burnley. Presidential Address, by Mr. W. A. Hartley; paper on "Cupola Practice," by Mr. J. Wood.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—The official returns show that there was a contraction both in the volume and value of the coal export trade of South Wales in August when compared with July. This contraction was partly due to that fact that there were two working days less in August than was the case in July, owing to the intervention of the holidays, and partly to the cautious policy generally adopted by buyers in view of the unsettled Continental position. In all, 2,326,520 tons of coal were shipped abroad from the four leading ports in August of a declared f.o.b. value of 3,097,445*l.* Compared with July there was a reduction of 229,905 tons and 404,902*l.*, respectively, while the average price per ton at 26*s.* 7*d.* was 10*d.* down. The shipments from the different ports were as follows:—

August, 1923.

From		Tons.	£	Per Ton. s.	d.
Cardiff	...	1,392,274	1,845,850	26	6
Newport	...	412,942	532,341	25	9
Port Talbot	...	225,799	294,160	26	0
Swansea	...	295,505	425,094	28	9
Totals	...	2,326,520	3,097,445	26	7

Compared with July, shipments from Cardiff were reduced by 49,000 tons, at Newport by 93,700 tons, at Port Talbot by 53,500 tons, and at Swansea by 33,700 tons. The average price realised for coal shipped from Cardiff showed a reduction of 5*d.*, at Swansea of 1*s.* 11*d.*, at Newport of 1*s.*, and at Port Talbot of 3*d.* per ton. Of the total exports large coal represented 63 per cent., through 3 per cent., and small 34 per cent., the quantities and values being as follows:—

		Tons.	£	Per Ton. s.	d.
Large	...	1,479,627	2,197,861	29	8
Through	...	76,740	90,211	23	6
Small	...	770,153	809,373	21	0

The yield of large coal was 7*d.* per ton less than in July, that of small 9*d.* less and through 3*d.* less. Of the shipments from Swansea, anthracite coal comprised 198,542 tons, valued at 317,058*l.*, compared with 215,579 tons valued at 370,940*l.* in July. Anthracite small realised 23*s.* 1*d.* per ton, or 1*s.* 2*d.* less than in July, and large 43*s.* 5*d.*, a reduction of 1*s.* Meanwhile, despite an improvement in the demand there is still insufficient business to absorb colliery outputs comfortably with the result that prices generally are irregular and dependent on individual circumstances. Some collieries are well placed, but the majority are in need of immediate business, and to buyers able to take quick delivery are prepared to make concessions. In order to avail themselves of the opportunity to secure cheap coal, merchants have of late been busily employed in chartering prompt steamers at slightly increased rates. For quick shipment, best Admiralty large coal is obtainable at 28*s.* with the leading Monmouthshires from 25*s.* to 27*s.* 6*d.*; though dry large is relatively strong at 27*s.* 6*d.* to 29*s.* 6*d.* Smalls, except coking sorts, are in plentiful supply at prices ranging from 13*s.* to 19*s.*, according to quality.

Iron and Steel.—Exports of iron and steel from South Wales last week amounted to 13,852 tons, compared with 14,482 tons in the previous week, and 20,456 tons a fortnight ago. Shipments of tin plates and terne plates totalled 5,811 tons, compared with 4,448 tons; black plates and sheets, 3,776 tons against 2,645 tons; galvanised sheets, 2,092 tons against 1,328 tons; and other iron and steel goods, 2,123 tons against 6,061 tons.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—The opening meeting of the session of this Institution will take place on Thursday, October 18, when Dr. Alexander Russell, M.A., will deliver his Inaugural Address as president. The premiums awarded for last session's papers will be presented on this occasion.

LARGE STEEL CRYSTALS.—In the current issue of *The Edgar Allen News*, Mr. J. S. G. Primrose describes a crystal of steel exceeding in size even the famed crystal of Professor Tschernoff, of St. Petersburg, of which a photograph appeared in *The Metallographist* during 1899. This crystal measured over 15 in. in length, but that described by Mr. Primrose was 19 in. long and weighed 3 lb. It was broken out of the pipe of a 50-ton ingot of mild open-hearth steel. Macrographs show that crystallites of ferrite were first formed and surrounded patches rich in carbon, which decomposed during slow cooling to form pearlite. There were also present inclusions of sulphides which were entrapped as the metal solidified.

1,500 B.H.P. TWELVE-CYLINDER TANDEM GAS ENGINES AT PALMERS SHIPBUILDING AND IRON COMPANY'S WORKS, JARROW-ON-TYNE.

CONSTRUCTED BY THE NATIONAL GAS ENGINE COMPANY, LIMITED, ENGINEERS, ASHTON-UNDER-LYNE.

(*For Description, see Page* 364.)

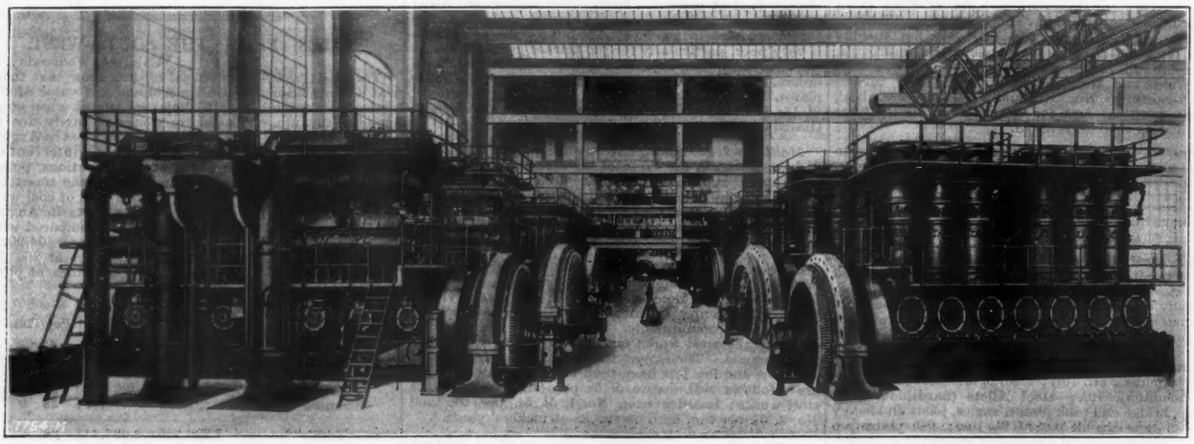


FIG. 31. GENERAL VIEW OF INSTALLATION.

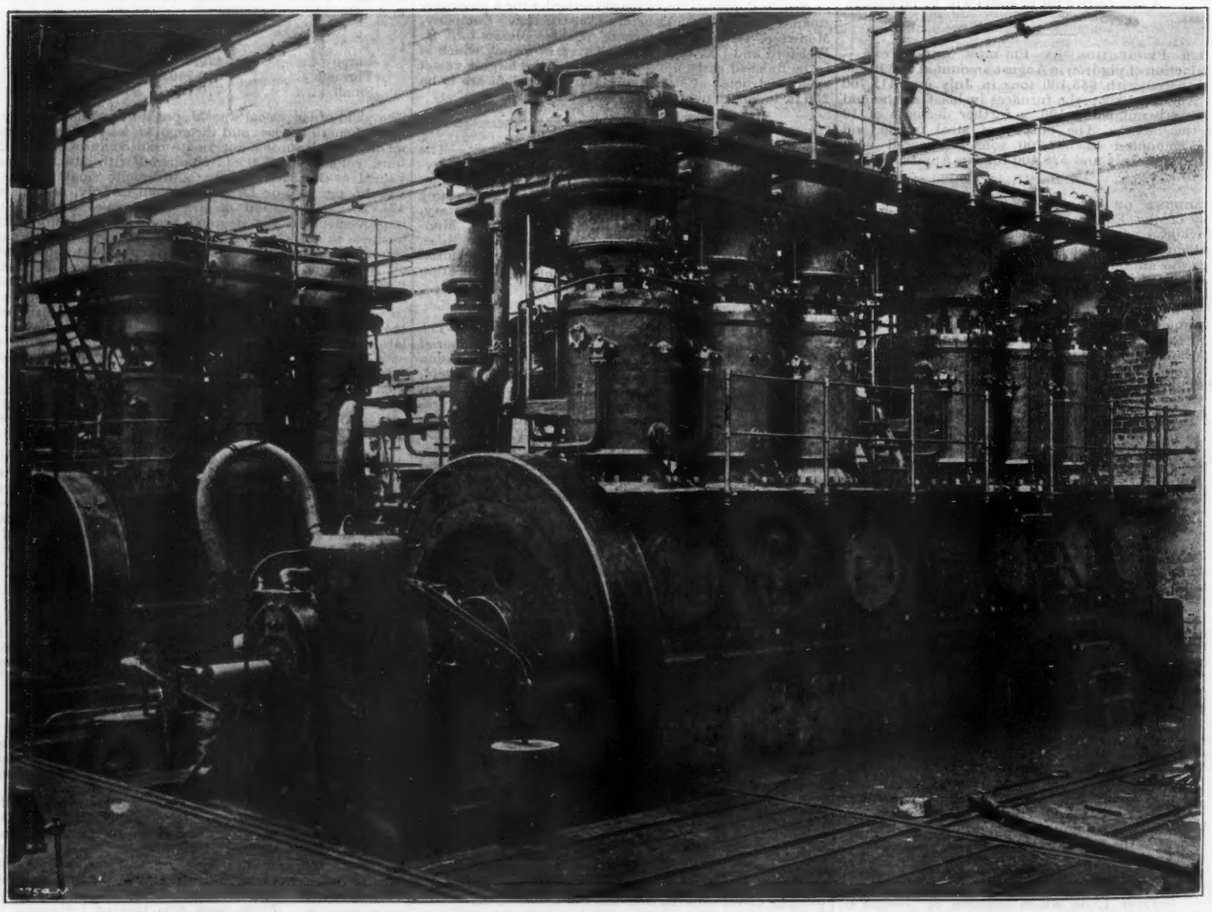


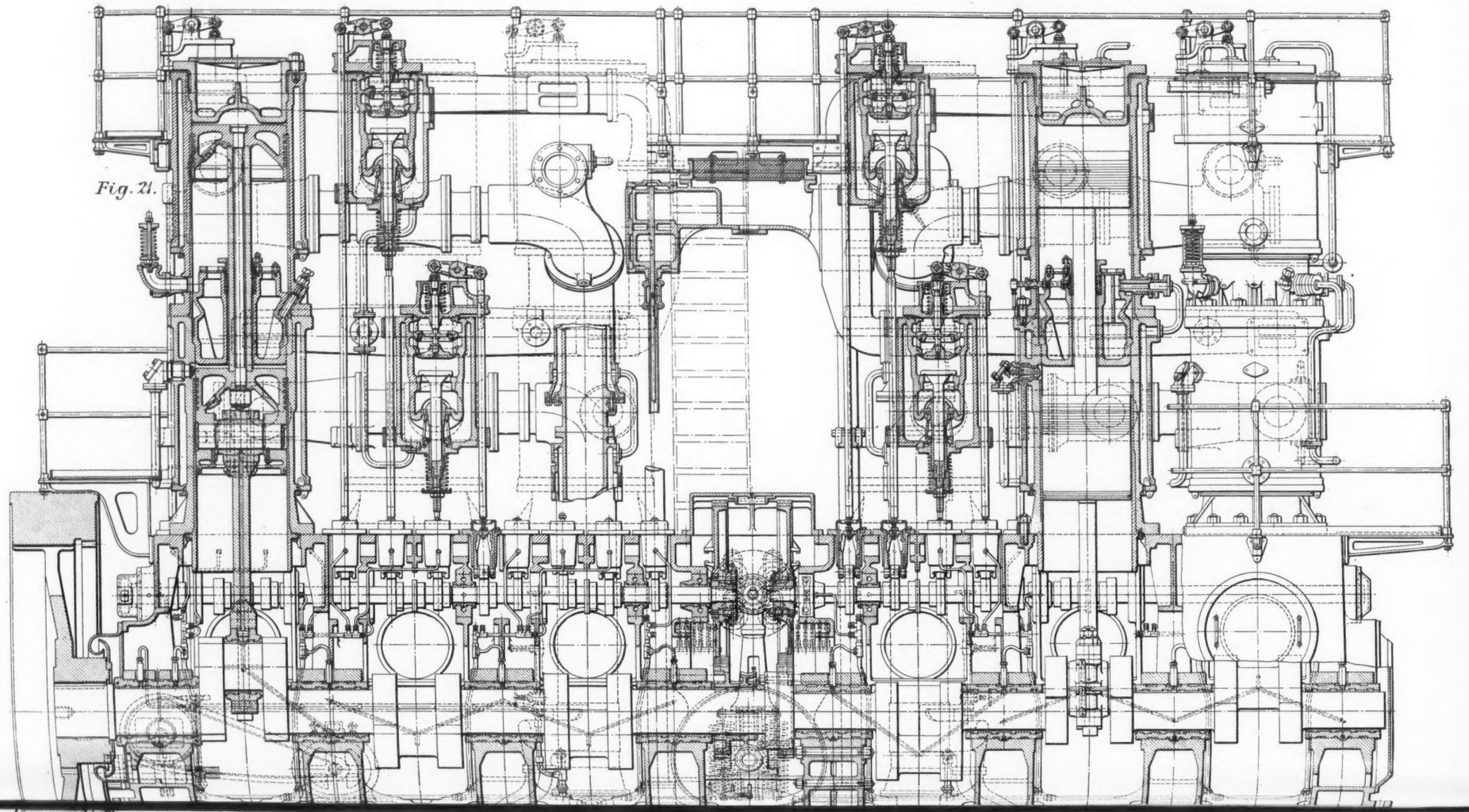
FIG. 32. ENGINE ON BRAKE TEST.

1,500-B.H.P. TWELVE-CYLINDER TANDEM GAS ENGINE AT PALMERS' SHIPBUILDING AND IRON COMPANY'S WORKS, JARROW-ON-TYNE.

CONSTRUCTED BY THE NATIONAL GAS ENGINE COMPANY, LIMITED, ENGINEERS, ASHTON-UNDER-LYNE.

(*For Description, see Page* 364.)

Fig. 21.



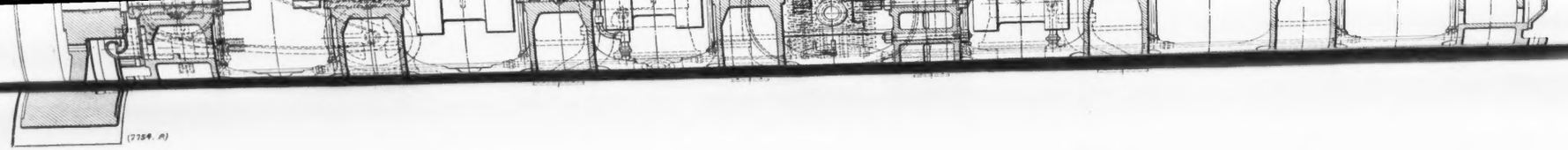


Fig. 22.

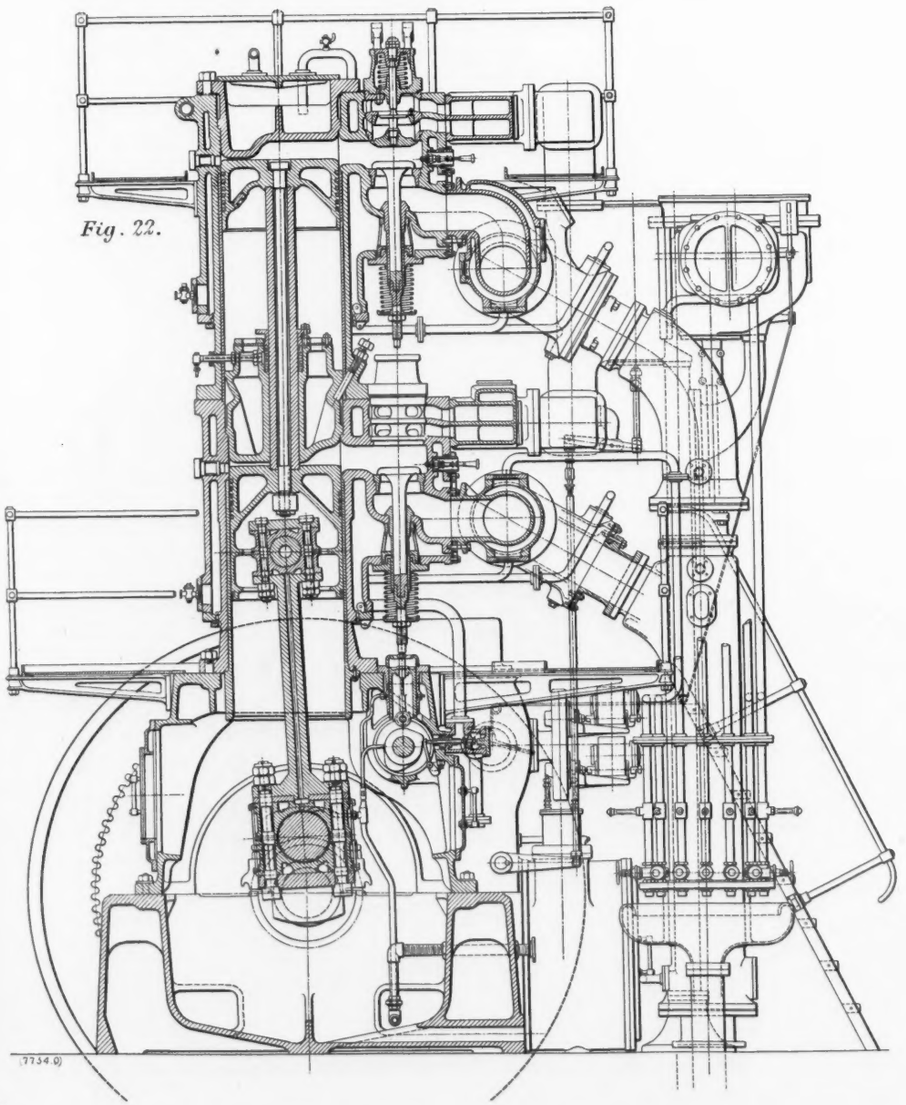
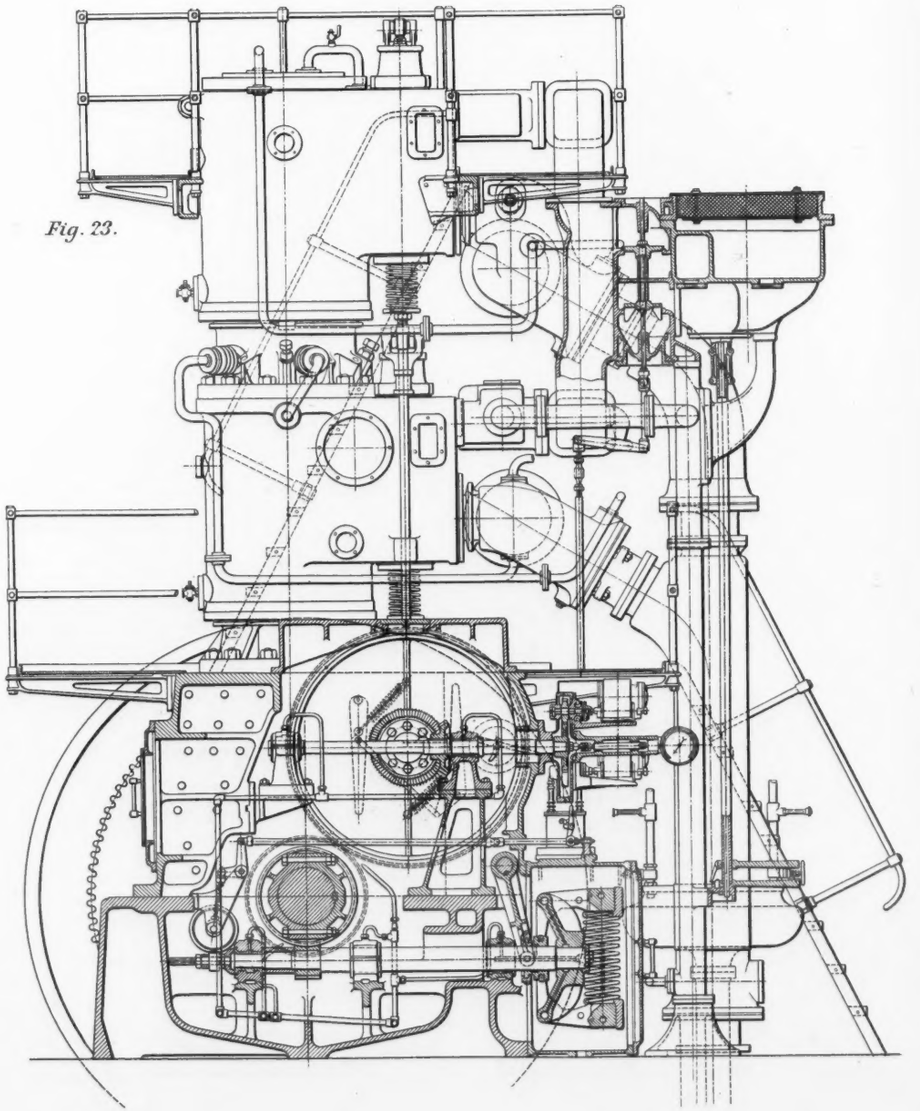


Fig. 23.



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TIME FOR RECEIPT OF ADVERTISEMENTS.

Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity of going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

All accounts are payable to ENGINEERING, LTD. Cheques should be crossed "The National Provincial and Union Bank of England, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford-street, Strand, W.C. 2.

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TASMANIA: Gordon & Gotch Prop'ty, Ltd., Launceston: Hobart.

UNITED STATES: For Subscriptions, New York: W. H. Wiley, 432, Fourth Avenue. For Advertisements: J. S. Allan, 30, Church-street, New York.

CONTENTS.

	PAGE
Deterioration of Turbine Oils in Use (*Illus.*)	353
The Shipping, Engineering and Machinery Exhibition at Olympia (*Illus.*)	353
The British Association (*Illus.*)	359
Industrial Notes	362
The Relation between Candle Power and Voltage of Gas-Filled Lamps (*Illus.*)	363
The Gas Engine Power Station of Palmers' Shipbuilding and Iron Company (*Illus.*)	364
The Water-Tight Subdivision of Passenger Ships	366
Letter to the Editor.—Steel Castings	366
Notes from South Yorkshire	366
Notes from Cleveland and the Northern Counties	367
Notes from the North	367
Notes from the South-West	367
Notices of Meetings	367
Boiler House Records	369
Protection from Gases	370
Air Filters for Motor Tractors	371
The Iron and Steel Institute	371
Notes	373
Notes on New Books	373
The Late Mr. J. B. Everard	374
Peterborough Electricity Supply	374
The Use of the Small Converter for the Production of Heavy Steel Castings (*Illus.*)	374
The Late Mr. A. J. Day	376
Horizontal Sewage Pump (*Illus.*)	376
Cohesion from the Engineering Standpoint	377
Transport and Its Indebtedness to Science (*Illus.*)	377
Road Transport	380
The Future of Transportation by Rail (*Illus.*)	381
Sea Transport	383
The Effects of Oxygen on Copper (*Illus.*)	383
Catalogues	384

Two-Page Plate.—1,500-*B.H.P. TWELVE CYLINDER TANDEM GAS ENGINE AT PALMERS' SHIPBUILDING AND IRON COMPANY'S WORKS, JARROW-ON-TYNE.*

ENGINEERING.

FRIDAY, SEPTEMBER 21, 1923.

BOILER HOUSE RECORDS.

THE attention which has been given of recent years to the more economical use of coal has resulted in the production of an enormous amount of literature dealing with the combustion of fuel, as well as of innumerable instruments designed to ensure that it is efficiently burnt in the furnaces. The ordinary power-station engineer, whose reputation, if not his livelihood, depends upon obtaining as much power as he can from the coal he consumes, is getting rather tired both of the exhortations and of the instruments which are offered to him. However much respect he may have for science, he knows in his heart that his boiler-house is not primarily either a chemical laboratory or an instrument-maker's show room, but a place where steam has to be made by the burning of coal. Analyses of fuel, flue gas, water, &c., all have their place, and instruments are necessary to carry them out and to provide such other indications or records as may be useful in operating. But such matters are subsidiary and indirect to the main purpose of the plant, which is simply and solely to produce the required amount of steam at the proper pressure and temperature with the least possible consumption of coal in the furnaces. If this obvious fact is admitted, it follows that the primary and essential measurements in every boiler-house are those of the coal burnt and the water evaporated, as the efficiency of operation is completely determined by the ratio between these two quantities.

If as much attention were paid to the provision of apparatus for securing these fundamental figures, as is expended on instruments which at best are only secondary and indirect guides to efficiency, there can be no doubt that boiler plant operation would be materially improved. This was one of the points strongly emphasised in Mr. W. E. Highfield's presidential address last week to the National Association of Supervising Electricians, in which he reviewed the principles of efficient boiler-house management from the practical standpoint which is so often neglected. The title of the address, namely, "The Manufacture of Steam," sufficiently illustrates the aspect from which he regarded the subject. A boiler-house was a factory, as much as any other manufacturing establishment, and the finished product, which was steam, must be turned out for the smallest possible expenditure of raw material in the form of coal. This could only be done by knowing both the consumption of coal and the output of steam, as without such knowledge the effect of any accidental or intentional variation in operating conditions, whether for good or evil, could not be brought to notice. It was, moreover, by no means sufficient to know the results at the end of a month or even weekly. For proper operation the figures must be available at the end of every 8-hour shift, so that any drop in efficiency could be noted immediately it occurred and suitable steps taken to effect an improvement.

We are very glad that Mr. Highfield expressed this view so definitely, as we have frequently emphasised the same point. A large power station may easily consume over 200 tons of coal on a single shift, and when coal is being burnt at this rate the immediate detection of any falling-off in efficiency is a matter of importance. The ideal condition is for the plant to be operated under the conditions of a simple continuous test, the readings of coal, water and electrical output being logged at intervals of 8 hours, coinciding with the changes of shift. Engineers not familiar with the details of power plant operation would naturally expect such figures to be obtained as a matter of course, but no one knows better than Mr. Highfield how rarely this obvious test of operating efficiency is, or can be, applied. Even in the large London central stations, it is quite the exception for the engineer to know how much electricity or steam he is getting for a pound of coal, except as rough averages over periods far too long to give the figures any operating value.

There is no need for laboratory precision in the apparatus measuring the coal and water. If a commercial accuracy of 2 per cent. is obtained it is all that is necessary, for it is doubtful whether the integrating wattmeters which measure the electrical output of the station can be relied on within this limit of accuracy. It is the continuous registration of performance, shift by shift, so that comparisons can be made, which is the essential matter, and not the perfect accuracy of individual observations. Elaborate boiler tests, conducted at intervals, are of little more than academic interest. They demoralise the station while they are being prepared for and carried out, and do much less to promote efficiency of operation than simple continuous records. Even if they indicated what a boiler could do under working conditions, they certainly do not show what it does do, for within half an hour after an efficiency of say, 80 per cent., has been shown on test, the boiler may be operating at an efficiency of 60 per cent., or even less without anything being very obviously wrong.

With regard to central station records, Mr. Highfield makes a remark which deserves consideration in businesses far removed from that of electricity supply. He holds it, he says, "a fundamental rule in connection with power plant matters, that no statistics are worth recording unless they can be made the basis of some action, either at the time, or later." Those who have seen the dusty and dog-eared collections of charts from innumerable recording instruments and gauges, and glanced at the sheets of unheeded figures to be found in so many engineers' offices, will appreciate the bearing of the remark. To take, as a mere matter of routine, a lot of records which are useless for the simple reason that it is impossible for the staff to analyse them is not only a waste of time, but has a bad moral influence, as it tends to bring the measuring instruments and their information into contempt. The plea that the necessity of taking readings ensures that the instruments are looked at every hour or less, is really a confession either of the ineptitude of the management or the superfluity of the instruments, for in a well-managed plant the operators can be relied upon to keep their eyes on every instrument whose indications are important or helpful to them. The station manager does not want to know, for example, what was the draught

across the grate of No. 15 boiler at 1.45 a.m., or what was the feed water temperature or the percentage of CO_2 at some other moment. What he is concerned about is whether he is getting a proper return on every shift for the coal consumed, and the details of operation from minute to minute can be left to the men in charge of the plant, unless a record is wanted for some definite purpose.

Presuming that the boiler-house was equipped with apparatus for ascertaining the basic figures of operation, namely the pounds of coal burnt and the pounds of water evaporated during every shift, Mr. Highfield proceeded to consider the best use which could be made of the data. The obvious course was to calculate the evaporation obtained per pound of coal, but the result so obtained was, as every engineer knows, not a true measure of the operating efficiency unless the magnitude of the load was taken into account. To emphasise this point, Mr. Highfield quoted an actual case, in which the evaporation on three consecutive shifts was, respectively, 6·367, 6·542 and 6·627 lb. of water per pound of coal. This variation was brought about entirely by the differences in output between the shifts, so that a direct comparison would be misleading and unfair to the operators. To overcome this difficulty and to enable the true relative operating efficiency to be determined, irrespective of the output, so that the performance of any shift could be usefully compared with that on any other, Mr. Highfield recommended the method devised several years ago by Mr. R. H. Parsons and now adopted in a good many stations in this country and abroad. The method, which has already been explained in our columns, notably in connection with our analysis of the Dalmarnock results last year, consists in plotting the total figures for the coal and water consumed per shift against the station output, and against each other. From a number of points so plotted, straight lines can be determined, and these lines can be regarded as the standard performances of the station. They form criteria by which every subsequent performance can be checked, regardless of the load on the station at the time.

Having once obtained these lines, the engineer has before him a simple, graphic method of comparing the operating results of the boiler-room, the engine-room, or the whole station, with standards which are attainable because they are derived from the plant itself. The evaporation figures which we quoted above are not in themselves comparable, but the discrepancies between them are found to disappear entirely when the total coal consumed on each shift is plotted against the total water. The points so obtained all lie exactly on the Parsons evaporation line for the station, so that the performances are all seen to be of exactly equal merit in spite of their apparent discrepancies. This line, for the case in point, is represented by the equation $C = 5{,}123 + 0{\cdot}1{,}487\ W$, in which C and W denote respectively the pounds of coal and the pounds of water used on any shift. The equation shows that, were there no steam used, 5,123 lb. of coal would be required to make good the boiler-house losses, and also that the evaporation would reach a limiting figure of 7·647 lb. of water with an indefinite increase in load. Deductions of a corresponding nature may be made with regard to the efficiency of the engine-room, from the line correlating steam and electrical output. It will thus be evident that, in addition to serving as a continuous graphic check upon operating efficiency, the Parsons lines bring to light important facts concerning the station as a whole, and Mr. Highfield's opinion that they constituted the most practical means of deriving immediate benefit from the coal and water records of the station is an authoritative tribute to their usefulness.

PROTECTION FROM GASES.

THE war was responsible for familiarising people with the gas mask. Prior to the use of poisonous gases at the front by the Germans, practically the only protection attempted was the fabric or cotton wool respirator, which was comparatively common not so long ago, even in the streets of London, when thick fogs were perhaps more frequent, and people were more nervous about their lungs and throats, than they are now. It will also be remembered that after the first poison gas attack an appeal, very readily responded to, was made for simple respirators, which, however, were no sooner received in hundreds of thousands than they were found to be ineffective against the gases used by the enemy.

The ordinary fabric or cotton wool respirator is, of course, as is now well recognised merely a filter, and the relief it affords is due to irritating solids being prevented from passing into the throat. It is effective according to the coarseness of the particles in suspension in the air, but may be only partially successful in contending with wood smoke and very fine dusts. As soon as it was realised in the war that something more than filtering was required the chemist came to the rescue, and catalytic action superseded. Charcoal and soda lime were adopted as giving protection against acid gases such as chlorine, phosgene, &c. This combination, however, is not of very wide application. It can be employed successfully against alcohol and benzene vapours, toluene, ether, &c., but it gives no protection against carbon monoxide, from which probably arise the greatest risks in industrial pursuits. Unlike most of the poisonous gases carbon monoxide cannot be detected by taste or smell. It is insidious in its effect, its presence being sometimes not detected before the victim is completely incapacitated.

This gas is, of course, not the only one from which danger may arise in industrial processes, and a respirator affording protection against it alone will not suit all circumstances. Where risk of poisoning by some particular gas is probable, as for instance following upon accidents in chemical or special works, respirators designed to meet the anticipated conditions would naturally be preferred. There is, however, the more general case of men having to work temporarily in an atmosphere charged with products of incomplete combustion, which conditions are to be met with in the performance of firemen's duties, or may occur in connection with gas works, blast furnaces, railway tunnels and other spheres of work. There are further to be considered the conditions which may arise in which work is necessary in an atmosphere, which, while not actually poisonous, is deficient in oxygen and so cannot support human life. For the latter, respirators are insufficient; the ordinary gas mask does not make good a lack of oxygen, and in these circumstances the worker must be supplied, as in mine rescue work, with oxygen-breathing apparatus.

Following up studies made of this subject during the war, the United States Bureau of mines has recently made a number of tests on masks for different purposes. As a result of these experiments three types of appliances have been evolved comprising two types of gas masks and a smaller apparatus which is merely a type of respirator. The gas masks are of the Tissot type, and fit, with soft rubber, completely over the face and communicate by means of a flexible rubber tube with a large canister slung by straps against the wearer's chest. The wearer draws in air through the canister and exhales it through a non-return valve in the mask. The two types of this apparatus are merely modifications in the matter of size and weight, coupled with the intention of making one rather more widely serviceable than the other. The absorbents are identical, but differ in amounts so that one appliance has a longer effective life in certain classes of atmosphere.

The absorbents used in the canisters are, in order from the bottom, where air is admitted, upwards to the top, where air is drawn off by the wearer, as follows: (1) Dry activated charcoal; (2) caustic soda fused on granular pumice stone; (3) fused calcium chloride; (4) hopcalite; (5) silica gel. The dry activated charcoal through which the air passes first absorbs organic vapours—alcohol, benzene, ether, &c. The second preparation is intended to remove the moisture from the air, while it absorbs carbon dioxide, chlorine, formic acid, sulphur dioxide and other gases. The calcium chloride which comes next in order is inserted to ensure the complete removal of moisture prior to the air passing to the hopcalite which only acts as a catalyst for carbon monoxide when in the dry condition. If moisture passes to this material its action fails, and as its inclusion is intended to ensure the removal of this gas whose presence cannot be detected by the senses; this safeguard is very important. The hopcalite changes the carbon monoxide in its passage into relatively harmless carbon dioxide. The top layer of material, silica gel, removes any ammonia which may be present, and organic vapours, and prevents moisture reaching the hopcalite from the upper end of the canister. The several materials are separated by wire screens and by cotton wool filters which vary slightly in arrangement in the two types of appliances.

The material termed hopcalite is a granulated mixture of oxides of manganese, copper, silver and cobalt, and the safe life of a canister for any service in which the presence of carbon monoxide is to be feared, depends wholly on the condition of this particular substance. Tests have shown that canisters containing 500 c.c. of hopcalite give an actual service of 14 hours at room temperature, but the safe life is placed intentionally at not more than 6 hours owing to the inability of the wearer to detect when the appliance fails to arrest carbon monoxide, and the risk that moisture may penetrate and destroy its action.

The smaller appliance is more portable and is meant for use where a less cumbersome design is advantageous, and more especially for firemen, as implied above. It naturally allows rather more freedom as regards physical action, but though the degree of protection is the same as with the larger appliance, the safe life is reduced owing to the lesser quantities of the absorbents carried.

The third type to which we have referred above is quite a small thing fitted with a rubber mouthpiece. It measures about 3 in. by 1¼ in. by 5 in. The mouthpiece is gripped by the teeth and when not in use the appliance can be put in the pocket. The canister normally contains activated charcoal, soda and lime mixture. A nose clip is provided so that involuntary inhallation through the nostrils is prevented. This respirator was designed to meet the need for relief to the men on large locomotives hauling heavy trains on up-grades through long tunnels. In such work contamination of the atmosphere is more troublesome than actual poison, the percentage of carbon monoxide present being usually relatively low, unless the engine stalls. The respirators have been tested in actual work in the United States, and are said to be popular where they have been tried. The conditions the men experience are in many cases most trying. The locomotives are very powerful. Often there are three to a train, moving very slowly and pulling so as to lift the fire right off the grate. Temperatures as high as 162 deg. F. have been measured for the tunnel gases entering the locomotive cab. Added to this heat is great humidity and the presence of smoke, and of irritants such as sulphur dioxide. From this some idea of the discomfort may be obtained though it is difficult to realise it without actual experience. Passengers on the London underground system of former days—now a passing memory—were inconvenienced to a degree which the more exacting present generation would consider intolerable—but their case was nothing in comparison with that of the enginemen of the trains they travelled on, and this, in turn, bore only a faint resemblance to the conditions of to-day on heavy locomotives working in long tunnels on limiting grades.

The small respirators we have described have an effective life of two or three months, used intermittently. As explained they are serviceable in tunnels under normal circumstances, but do not protect against unusual conditions or in the case of a stoppage, when the percentage of carbon monoxide may rise to a dangerous figure. There have, of course, been several cases of CO poisoning under such conditions, but the occurrences are rare and are difficult to guard against, especially when reliance has to be placed on a material like hopcalite, in the use of which such great care has to be exercised.

While in many cases the carbon monoxide percentage does not rise to a dangerous degree, in others it is found to be present to such an extent that, coupled with excessive heat and humidity, physical collapse has resulted. This has occurred on the Aspau Tunnel on the Union Pacific Railway—a tunnel over a mile long close to the Continental

Divide, and in the Wahsatch Tunnels in the same area. Owing to the heat and effects of the high altitude—nearly 7,300 ft. above sea level—the type of gas mask described above did not make conditions much better for the men, and resort was had to an ingenious expedient which, however, could not be applied under all circumstances. It was found that the air brake supply did not become contaminated for some time after entering a tunnel, and the train pipe was therefore tapped and flexible hose pipes (with masks) were arranged for the train crew at their several posts. The air brake atmosphere was used drawn through a rough sponge filter, and the risk from carbon monoxide and troubles from irritants were virtually eliminated.

AIR FILTERS FOR MOTOR TRACTORS.

WHEN the internal-combustion engine was introduced to the propulsion of road vehicles and in the driving of agricultural implements, there were found to be many natural conditions which imposed limitations on its general adoption. With the accumulation of experience and the application of the results obtained in tests in the works, as well as in actual service, the number of these has been gradually reduced until they have been almost eliminated. Recently, we described in ENGINEERING (page 140 of the present volume), a commercial vehicle designed to work under the trying conditions imposed by extreme altitudes. In that case the motor had to run with reliability and regularity where the atmospheric pressure was only 8·3 lb. per square inch. Similar resourcefulness has been shown by the designers in dealing with other troubles and in the production of equipment which will withstand the most exceptional treatment.

A problem of great interest is that of dealing with the abrasive dust found in many places where the extended use of motor traction is desirable. The effects of the dust, turned up in the course of running by a car or tractor, upon the wear characteristics of the component parts of an engine vary in a marked way with the properties of the dust. In arid regions, where the soil is of a silicious character, the dust raised by a tractor is very abrasive and rapid wear is a consequence. To ensure continuous running in such a service, the direct entry of dust-laden air into the engine must be prevented. Maintenance costs can in that way be reduced and the life of the working system of the tractor greatly extended.

Many types of air filters are available and may be classified as water cleaners, the dry type and those using oil. In the first class the dusty air generally passes by a pipe into a hollow float and is drawn through water where it is broken up by perforated baffles while other plates prevent the carrying over of drops of water. Some few make use of water sprayed in a finely-divided state into the air, while in others metal vanes guide the air into circular motion as it enters the water, and in some, churn up the water to produce a spray effect. Centrifugal actions to throw the dust to the casing walls are used in some plants of the dry type, while in others simple dry cloths are used as filtering mediums. Fibrous material saturated with oil and the spraying of oil into the air and its later separation by baffles, are the methods used on the third type of apparatus to remove the dust.

Little information has been available to the general engineering public as to the relative efficiencies of the various types until recently. Tests were made by the manufacturers, and where any results were given, the conditions under which the investigations were conducted were so different from those used by others, that comparison was almost, if not completely, impossible. It is for that reason that we welcome a contribution from an experimenter who has endeavoured to obtain standard conditions for a series of tests on the different types. The results of these investigations are embodied in a paper on "Efficiency of Dust Separation in Air Cleaners for Internal-Combustion Engines," which Mr. Arthur H. Hoffman, of the University of California Agricultural Experiment Station, gave to the American Society of Agricultural Engineers.*

* *Agricultural Engineering*, Vol. iv, Nos. 6 and 7, June and July, 1923.

In all experimental work of this character the first considerations relate to the fixing of the conditions of working. Without doubt, field tests under comparable conditions and extended over long periods, would be the most informative, but the time taken up and the disturbances caused by variations in wind velocity and direction, the changes in the humidity of the atmosphere and the alteration of the moisture content and other characteristics of the soil, put that method quite outside the scope of practical possibility. Laboratory tests present many difficulties also, but with resource they may be overcome and uniform standard conditions obtained for all the work. In Mr. Hoffman's research he used a standard tractor engine of 22½-h.p. rating, which was run under similar conditions for the tests on each dust separator.

The principal items in the preliminary work was the obtaining of a satisfactory standard dust, the devising of a proper mechanism for feeding the dust into the clean air before it was passed to the separator, and the discovery of an accurate means of determining the percentage of the total dust arrested by the cleaner. Screening was found to be an unsuitable method of obtaining a standard material, as the dust caught, in the dry type of cleaners used in California, was so fine that 99 per cent. would pass through a 200-mesh per inch screen. Air floating was used to obtain a satisfactory substance from dried and pulverized soil. Actually, two standards dusts were used, the finer one for the general efficiency tests and the coarser in a series of experiments in which the cleaners were allowed to "fill up." The weighed charge of dust was pushed forward in a short metal tube at a uniform rate and thrown into the air by a rotating bristle brush. Every endeavour was made to procure standard conditions by having an electrically-operated feed system and a fixed speed for the motor. The comparison of the efficiency of the cleaners presented some difficulties, evaporation losses introduce variable errors in the tests of the oil and water types of apparatus, and in some of the dry form, the dust which is removed is ejected into the open air. The method adopted was to catch on an accurately-weighed material the dust allowed to pass through by the cleaner. For this purpose, squares of eiderdown blanketing were stretched on wooden frames and clamped in a sheet metal pyramid. The efficiency was determined on the basis of what the extractor arrested and what it allowed to pass through.

The effect of the presence of the cleaners on the power of the engine was found to be very slight when they were clean. The average efficiency obtained with the dry plants was found to be 73·8 per cent. when the engine was run for periods at certain fixed loads, and 71·3 per cent. when there was variation of running to a definite scheme, in an attempt to represent the common running conditions. The dry system that showed up best was the use of cloths as a filter medium with which the results varied between 97·8 per cent. and 99·5 per cent. Of the others, those in which every endeavour was made to obtain a rapid whirling of the air proved the next best.

The wet type of dust extractor was shown to be very efficient, those using water cleaning giving efficiencies of 93·6 per cent. on fixed load and 93·4 per cent. on the variable loads representing usual conditions. Better results were found, however, when oil was used for the dust removal. For cleaners of that nature the average efficiencies for fixed loads and standard running variations were 98·5 per cent. and 98·6 per cent. respectively.

The report of an experimental investigation, in which great difficulties were experienced in obtaining a common basis of testing and comparison of the results, is interesting as an illustration of how such troubles may be overcome with the exercise of resource. Mr. Hoffman's work has served a very useful purpose in the demonstration of the utility of air filters in keeping down, to very small proportions, the passage of dust into the engine cylinders, and in indicating their significance in preventing the attritive actions, of fine abrasive material on the mechanism of a tractor or motor car, particularly in regions where very dusty conditions of the air are experienced.

THE IRON AND STEEL INSTITUTE.

FOR the first time in its history the Iron and Steel Institute held its annual autumn meeting this year in Italy, by kind invitation of the president (Comm. G. E. Falck), and Council of the Italian Association of Metallurgical Industries. No more appropriate centre could have been selected than Milan, the second largest town in Italy, and the industrial and banking capital of the country. The reception committee was formed of His Excellency Benito Mussolini, President of Council, a large number of Italian Ministers, Senators and Deputies of the Italian Parliament, and other influential gentlemen. The Hon. President of the Executive Committee was Comm. G. E. Falck, and the acting-president, Professor Federico Giolitti, while the members were well-known Italian engineers and metallurgists.

The members of the Institute assembled last Monday morning, the 17th inst., at the Milan Chamber of Commerce, where they were most heartily welcomed by Comm. Falck. It was a welcome, said the speaker, which he would have liked to have been able to extend to the Institute in 1911, when the autumn meeting was planned to take place in Turin, on the occasion of the celebration of the fiftieth anniversary of the Italian unity; but obstacles intervened at the time and the meeting had to be postponed. Comm. Falck referred to the late war, when Italy and Britain were one and undivided in their sentiments, both countries fighting side by side for the highest ideals, and winning the victory. It was a great satisfaction to him, as president of the Italian Association and hon. vice-president of the Institute to receive the members. Italy, owing to the natural circumstances prevailing, could not boast of the imposing development which had marked the British metallurgical industry. However, during the rapid visits the members would make of a few Italian works they would be able to ascertain the improved economical and political conditions of the country, also the conspicuous progress made by the Italian iron and steel industries. A new Italy had arisen with the coming into power of the National Government. Italy intended to make herself esteemed by several features, but especially by her productive work in industry and agriculture brought about by the cordial co-operation of labour and capital. Britain, who was proud of her traditional friendship towards Italy (and Italy fully reciprocated that feeling), would certainly understand the new spirit animating the new generations, welded together as they had been by the hardships of war. He expressed the hope that the meeting in Milan and the subsequent visits to be paid would strengthen that longstanding and sincere friendship which had always united the two nations and which had seemed undermined for a few moments by recent events. And with the expression of this heartfelt hope, he invited the meeting to commence its work to the wish of "Long live both countries!"

Comm. Engineer C. Vanzetti, C.B.E., said that in the absence of the president of the Milan Chamber of Commerce, it fell to him as the oldest member of the Council of the Chamber to welcome the Institute in their building. He felt sure the members would see that progress had been made in the country's industrial pursuits, and when they left they would take away with them new ideas concerning the new Italy, which owned important industrial establishments besides her art treasures.

The president, Mr. F. Samuelson, thanked Comm. Falck and Comm. Vanzetti for the splendid reception afforded the Institute. All the members of the Institute reciprocated what had been said with reference to the cordial relations between the two countries. Italy and Britain were friends of longstanding, and all admired what Italy had done in Arts and Science. In regard to science, Italians had been among the earliest in the field; in astronomy and electricity, for example. A great many electrical terms were Italian. Italy had been greatly handicapped in carrying out her magnificent industrial development by the lack of many resources. She had not the coal, as Britain and the United States had; she had, however, numerous water-power facilities. He thanked the Chamber of

Commerce through Comm. Vanzetti for placing the building of the Chamber at the disposal of the Institute for the present meeting.

The Iron and Steel Industry of Italy.

The first paper taken at the meeting of Monday morning, the 17th inst., was one by Comm. G. E. Falck, hon. vice-president of the Institute, and president of the Association of Italian Metallurgists. It was read in abstract by Professor Mario Hazon. The paper reviewed the progress made in agriculture, industry, commerce and finance. In regard to industry, Italy lacked raw material generally and coal in particular, but it had available large water-power resources, an abundance of highly-skilled labour, and its geographical situation was exceedingly favourable to trade. All the hydro-electric installations at work in 1914 developed a total of about 970,000 h.p.; in 1922 the total was 1,480,000 h.p. Industry, however, had developed at a pace more than sufficient to absorb all the new power available, and the new water power installations did not suffice to supply all the needs of the new enterprises. Strikes no longer took place; stoppages of work on the flimsiest of pretexts had practically ceased. The new Government, which ruled the destiny of the kingdom, had shown that it respects private enterprise, and the policy of penalising capital had been arrested. A sense of discipline had been re-established, and producers of every class had regained confidence.

Dealing more particularly with the iron and steel industry of Italy, Comm. Falck said that at the outbreak of the war, in 1914, the country produced 420,000 tons of pig-iron and 930,000 tons of steel annually. The output of steel rose to 1,304,000 tons in 1917, this affording an illustration of the successful efforts made in Italy to meet the war requirements. Since then the productive capacity has increased; in 1920 there were upwards of 100 iron and steel works, comprising six coke blast furnaces, 8 charcoal furnaces, 20 electric furnaces producing synthetic pig-iron, 107 open-hearth furnaces, 4 converters and 96 electric furnaces. In 1921 there were 11 blast furnaces and 170 open-hearth furnaces. In 1922 the electric furnaces had increased to 113 of large and medium size, and 60 of small size. The material was transformed either in the same works, or in others having rolling mills, merchant mills, or again in establishments in which the rolled material was worked up.

Sir Hugh Bell, Bart., C.B., said his knowledge of the Italian industries went back many years, and he, like all others who knew those industries, greatly admired the work done in Italy under very difficult conditions. During the war, our conduct in the matter of coal supplies may have left much to be desired; the scarcity of our supplies made matters very difficult for Italy, and he took that opportunity for expressing his regret. Britain delighted in and admired the efforts put forward by Italy. We were perhaps too apt to lay great stress upon natural resources and not enough upon mental qualities, and in this latter point Italy was in a good position. We should be very ungrateful were we not to tender to Italy to-day our thanks for what she had done both now and in the past ages. We looked to the prosperity of the country, and in this connection he might add that the prosperity of the world at large was desirable for every individual man.

Mr. F. Samuelson, the chairman, said the paper was a most appropriate one to open the proceedings, in that it gave a general review of the Italian metallurgical industries from the earliest times, and the present situation. The visits to be paid to the various works on the programme would afford a no less appropriate illustration of Comm. Falck's contribution to the proceedings.

Manganese in Steel Manufacture.

The second paper taken at the meeting on Monday morning, the 17th inst., had for its title "The Complex Action of Manganese and Other So-called Deoxidising Agents in the Manufacture of Steel," by Dr. Federico Giolitti; it was read in abstract by the author.

In this paper, Dr. Giolitti made it clear that he was dealing with everyday steel manufacture in the open-hearth furnace and not with laboratory experiments. He stated that the phenomenon generally known as transverse weakness was characteristic of the "oxidised" steels, or of those "not thoroughly deoxidised" during the melting process and before teeming. One of the main causes of transverse weakness was the presence of non-metallic inclusions in the steel. The paper gave the figures of several actual charges, in which additions of pyrolusite MnO_2, or of ferro-manganese, were made, and pointed out that the purifying effect of the manganese could not be solely due to a process of deoxidation, but also to a specific action which the manganese exerted on the steel bath when it had passed in solution in the metallic state, and when it could not longer by itself exert a reducing action. The manganese, apart from its true deoxidising property, acted in facilitating the processes of physical separation of the non-metallic inclusions emulsified in the liquid steel.

The discussion was opened by Dr. W. H. Hatfield, who said he had read the paper with great interest and found it a valuable contribution to the subject. It was of first-rate importance to all steel-makers in that it put forward a new point of view to the effect that it was not sufficient to look simply at the chemical reactions which took place in the bath. Other features had to be considered also. Manganese when added in the presence of oxygen became manganous oxide, and, taking the hypotheses of the author, one had to consider the behaviour of manganous oxide and also of manganous silicate probably in colloidal form in the steel. One aspect of woody structure should not be lost sight of, and that was the teeming temperature, and this came in quite apart as to how thoroughly the steel had been deoxidised in the furnace, the segregation in the ingot being different when the steel was teemed hot or comparatively cold. British metallurgists gave due recognition to the work of Italian technical men; they looked upon Dr. Giolitti as a leader, and his book on "Case-Hardening" was to be found in the works' libraries.

Mr. J. A. Matthews stated that the residual manganese throughout the manufacture of steel had a good effect, and the subject of residual manganese received a large amount of attention in the United States. He thought the beneficial action of manganese in the bath during the early and at all stages was to prevent the bath from becoming "sick," followed by the necessity of applying remedial reagents at the completion of the heat, with consequent uncertain results.

Mr. S. E. Lester found that many of the good qualities obtainable in steel did not depend so much upon quantities or figures, but upon the actual method of arriving at a definite workable result to give the inherent qualities required of best steel. Craftmanship entered into the matter quite as much as chemistry and physics, all bearing at the right time upon the process whilst this was being carried out.

Mr. E. L. Dupuy said the contribution by Dr. Giolitti was the most complete one made on a subject which had been discussed but seldom hitherto. He (the speaker) had occasion to make oxygen determinations by hydrogen reduction on steels manufactured by the basic process in the presence of manganese during the whole operation; even when the steel gave good transverse tests some water was formed, showing the presence of an oxide which was neither MnO nor SiO_2. He added, he would very much like to know how Dr. Giolitti explained the presence of the oxide left, and whether he admitted that the good transverse tests were due to a change in the chemical composition of the oxide or only to its distribution.

Mr. C. H. Ridsdale stated that years ago he had occasion to study very closely in the basic Bessemer process the action of manganese. The steel made was then called "electric steel," now called "conductivity steel," containing low carbon and low manganese. To prevent the material from being short he added plenty of manganese at the beginning. One way, quite at the beginning of the charge, after the silicon had been blown out, was to add spiegeleisen; this was also blown out, and he had to add more spiegel several times during the process. He took slag from the top of the ingot and found in it a high manganese oxide with the impurities in the steel liquating out. He would give in writing more complete data of the results he obtained.

Dr. Giolitti, in the course of a brief reply, thanked the meeting for the good reception given his paper. He confirmed the remarks of Dr. Hatfield in regard to the teeming temperature, and added that the elimination of the inclusions was due to the flocculent effect of manganese. He only put forward his theory, his paper did not solve the problem, and he greatly appreciated the remarks which had been made by the various speakers.

Small Converters for Heavy Steel Castings.

The third paper taken at the meeting on Monday morning, the 17th inst., had reference to "The Use of the Small Converter for the Production of Heavy Steel Castings," communicated by Comm. Engineer C. Vanzetti, C.B.E. The paper was read in abstract by Professor Mario Hazon. We publish this paper in an abridged form on pages 374 and 375 of the present issue.

It stated that the Steel Foundry of Milan was put down in 1888 and produced light steel castings with the small Robert converter. In 1894 the works started the production of large castings using the converter alone. Later on they used the converter in conjunction with a receiver for the molten metal. Most of the stems, stern and rudder frames for Italian merchant ships and warships had been cast by the company's method.

Sir William H. Ellis, who opened the discussion, called attention to the English honour which had been conferred upon the author for the services he had rendered our country, and offered him his and the members' congratulations. The Robert process was followed at his (the speaker's) works for the last thirty-five years. The results obtained by the castings made under that process had been quite equal to those made by any other. It was a very advantageous process when dealing with comparatively small weights, of 1 ton to 3 tons, when it was possible to obtain a variety of results according to the requirements. It was well under control, and most suitable for a series of small castings. One had merely to tilt the converter for each casting, the metal therefore being supplied for each casting direct from the converter. Both the Tropenas and the Robert processes when they first came out were not viewed with much anticipation as to their success, but they had both survived, and their convenience, coupled with their accuracy, had led to their continued use and to their popularity.

Dr. W. H. Hatfield confirmed Sir William H. Ellis' remarks. The process followed in Italy, as stated in the paper, was good; it was also followed at Scunthorpe. It was, one might say, a descendant of the Bessemer process, and a magnificent one for the manufacture of castings. The manganese, if run a little higher, would yield an advantage. The author's statement as to the test figures were rather conservative; for instance, he mentioned 20 per cent. elongation, whilst he (the speaker) obtained 25 per cent. to 30 per cent. But the figures obtained were largely determined by the heat treatment.

Comm. Vanzetti said, in reply, that although the converter was not the best apparatus for making steel, for special uses in the making of small, and also of large castings, it gave, as he had pointed out, excellent results.

The Next President of the Institute.

At this point, the chairman, Mr. F. Samuelson, announced that the president for the forthcoming year would be Sir William H. Ellis. The announcement was received with acclamation.

The Corrosion Cracking of Steel.

The fourth paper taken at the meeting on Monday morning, the 17th inst., dealt with "The Corrosion Cracking of Steel under the Influence of Internal Stresses." It was contributed by Mr. A. M. Portevin, and was read in abstract by the secretary.

It entered in detail in the investigation of the cracks observed in shells after banding, followed by pickling, or by contact with certain chemical products, which investigation showed that certain corrosive reactions may determine cracks in steel which was in a condition of internal stress, and that these cracks may spread to the interior of the metal. It further showed that these influences were comparable to the phenomena observed in regard to

brasses and aluminium and sometimes described under the name of "season cracking" or "corrosion cracking."

The discussion was opened by Dr. W. H. Hatfield, who stated that a large amount of work had been done on the subject with reference to non-ferrous metals, but little in the matter of steel. Mr. Portevin had therefore rendered metallurgists a great service in contributing his present paper. Just before the war, and also during the war, emphasis had been laid on notched-bar tests, but good impact tests and the absence of quenching stresses were almost impossible to obtain together in the same piece. Engineers would have to modify their requirements. The author, besides, had also brought in corrosion, and this increased the value of his contribution.

Dr. Giolitti found it important to deal with the great effect which small cracks may have on large masses of steel as compared with the effects of inclosures, and Mr. E. L. Dupuy agreed with Dr. Hatfield's remarks, which pointed out to engineers that it was impossible to have both results—good impact results and the absence of quenching stresses—from the same piece, especially when large.

(To be continued.)

NOTES.

National Gas Exhibition at Birmingham.

In the years which have elapsed since the last gas exhibition was held in this country, there has been considerable progress made not only in the improvement of appliances, but also due to the increased activity in connection with the extraction of derivatives and to the changes in the character of the product permitted under the Gas Act of 1920. The time is thus an opportune one to demonstrate to gas engineers and to the public generally, what has been done in recent years. The present exhibition in Birmingham was opened on Monday last by the Right Hon. the Lord Mayor of Birmingham, Sir David Davis, who was supported by the Chancellor of the Exchequer, Mr. Chamberlain, Mr. D. Milne Watson, the president of the National Gas Council, Sir Arthur Duckham, K.C.B., representing the Society of British Gas Industries, and Alderman J. H. Lloyd, president of the British Commercial Gas Association. An historical exhibit loaned by the Public Libraries Committee of the City of Birmingham has many items of exceptional significance to all who are interested in tracing the lines of progress of a modern industry from its start. In the general show every effort has been made by the manufacturers to demonstrate the value of gas to commercial and domestic users, and if the quality of the exhibits is any criterion of its success, the hopes of the organisers should be more than satisfied. The exhibition remains open until Wednesday, October 3, and on the last three days the annual general meeting and conference of the British Commercial Gas Association will be held in Birmingham, when many public lectures connected with the use of gas in the home and in particular industries, will be delivered by members.

Industrial Fatigue.

It is to be regretted that up till now no evidence has been published that the Industrial Fatigue Research Board is taking steps to associate engineers with the planning and execution of investigations relating to engineering matters. That investigations such as those of the Board may be of the utmost value to the industries concerned is beyond question. It is equally certain that so far as these investigations have related to the engineering trades they have hitherto failed to attract the interest and confidence of those trades, because they have been made solely by persons who have not had the necessary first-hand familiarity with the conditions, technology and shop practice of the trades in question. Already in these columns (ENGINEERING, January 26 and May 4, 1923) explicit reasons have been given for the conviction that an inquiry into the fatigue produced by an engineering process demands necessarily the intimate co-operation of an unusually skilled and experienced engineer, if it is to be of real value to the industry in question. There is no reason for repeating what we then urged, which to engineers was little more than commonplace; but a sufficient interval has elapsed since the later of these observations to warrant the expression of the hope that the matter is not being lost sight of. Among the work that the Board was said, in their last annual report, to be contemplating, was an inquiry into the possibility of improving machine design so as to reduce the fatigue involved in operating. The variety of constructions that would be affected by such an inquiry indicates the investigation as one that would require a high variety of engineering qualifications, both practical and technical, in its planning and execution. This purports to be an inquiry of large scope and great importance and some indication that it is being, or will be, conducted on lines that would be satisfactory to engineers would be valuable, not only as giving satisfaction to a body of men whom it would be desirable to interest in the Board's general work, but also in increasing the prospect of their giving useful co-operation in the particular inquiry in question.

NOTES ON NEW BOOKS.

Probably for one person who is at present or is likely to be engaged in the design of steam turbines, there are at least one hundred employed in the manufacture and operation of these machines. This numerous body is little concerned with any but the most general notions of thermodynamics and hydraulics, but has a very immediate interest in details of construction and methods of erection, adjustment and operation. The needs of this class are extremely well met by "*Steam Turbine Principles and Practice*," a book published at 15*s.* net by the McGraw-Hill Publishing Company, Limited, London. The author is Mr. Terrell Croft, Member of the American Society of Mechanical Engineers, and the illustrations and text are based practically entirely on American practice, which is, however, no drawback, though we note that occasionally the terminology differs from that in use here. The descriptive matter is very complete and the notes on erection and adjustment are well considered. There are also chapters on operation and testing and on the use of correction curves, and some interesting notes on economic considerations. The private student will find the numerous questions and exercises appended to many of the chapters very valuable, as they provide him with the means of testing his understanding of the text.

When the steel industry was in its infancy the roofs and linings of furnaces were a constant source of trouble and anxiety to metallurgists, and progress was only made possible by the study and consequent better knowledge of refractories. The modern open-hearth furnace with its smooth and efficient working and its large and continuous output is the result of years of patient research not only in the spheres of metallurgy and the physical chemistry of fuels, but also in the realm of refractories; in fact, the whole history of steel is linked up with that of the fire-brick. At the present time, when electric furnaces are being utilised more and more, the success of the metallurgist depends, to a large extent, upon the efforts of the expert on refractories and, one is bound to admit, the latter's work is not always given full appreciation. "*Refractories for Furnaces, Crucibles, etc.*," by Alfred B. Searle, London (Sir Isaac Pitman and Sons. Price 5*s.*) is an attractive little work in which the characteristics of the chief raw and manufactured refractory materials and the processes and machinery employed in their production are described. When dealing with finished bricks, the author not only gives important practical details such as zone of refractoriness, degree of shrinkage or expansion on reheating, crushing strength, and effect of pressure at high temperatures, but also writes on such subjects as mineralogical composition describing the various minerals present, their influence, and how to detect them under the microscope. He shows how much information may be gleaned concerning the superiority or otherwise of finished refractory materials by careful examination under low-power magnification. Having given the reader a good insight into the properties of the finished products, the author describes the raw materials from which they are manufactured. The data given are chiefly of a scientific nature and are very complete and well set out. A section is devoted to the shaping of refractory ware, and the machines used in the various processes are illustrated and described. The all-important processes "drying" and "burning" are dealt with in detail. The whole subject is admittedly a complex one, and the author is to be congratulated upon the neat and methodical way in which he has arranged his information. The book deserves a wide circulation among scientific as well as practical men.

In our issue of June 1 we noticed, on page 681, a book on "*Passungs Systeme*," by Dr. Ing. O. Kienzle, dealing with the general principles of tolerances and of manufacturing to limits. Since then Dr. Kienzle has edited another volume on these problems, under the title "*Der Austauschbau und seine Praktische Durchführung*," which may be translated, "Construction on the interchangeability system and its practical application." This latter volume of 320 pages with 319 text figures [Berlin: Julius Springer, price 8*s.* 1*d.*] is a collection of twelve lectures delivered by different experts in the winter 1921-22, on behalf of the "Arbeits gemeinschaft Deutscher Betriebs-Ingenieure." Dr. Kienzle and Professor Gottwein again deal with the general problems, while Messrs. G. Berndt, J. Reindl, E. Huhn, K. Gramenz, Gohlke, G. Leifer, C. W. Drescher, G. Frenz and T. Damm give their views on interchangeability in the construction of measuring machines, of tools for cutting, drilling and polishing, and in automobiles, roller bearings, mechanical apparatus, electric machinery, engines and locomotives. The lectures were independent, but they have been suitably edited. Since the standardising committee of the Verein Deutscher Ingenieure took up the question of tolerances and limits in 1917, a good deal has been written and done in this field in Germany, and locomotives were constructed last year on the interchangeability system with tolerance in the hole; the latter had been approved by 31 out of 35 firms and authorities. The Kösters interference apparatus for determining differences in the length of end measures will probably be novel to most readers; it is mentioned, together with various English devices, in Berndt's section on measuring tools.

Mineral oil properly so-called has so many applications, and the possibilities in store for its substitutes, whether they proceed from the mineral or from the vegetable kingdom, have become so vital to many countries, that complete data on all of these products are always welcome. Such details are given in a volume measuring 11 in. by 8¼ in., entitled "*Chimie et Industrie*," just published by the journal of the same name as a special number, and recording the proceedings of the Liquid Fuel International Congress, which was held in Paris last October. The congress was divided into several sections, dealing respectively with petroleum, shale, lignite and peat, tars and benzoles, alcohol and vegetable oils. The sources of supply, the treatment of the crude material, the testing of the products obtained and their utilisation, are reviewed in detail in the numerous papers forming part of the volume. The advisability from an economical point of view of using alcohol and vegetable oils for industrial purposes, in the place of mineral spirits and oil, formed a feature of the congress, and all who are interested in this point will find much interesting information in the papers under these sections in the volume. The French members laid great stress upon the economical advantages to be derived by turning to account the vegetable oils obtainable in large quantities in the northern and central African French colonies, in Madagascar and in New Caledonia, and in using these oils in preference to the mineral product. French engineers have been working at this problem for several years past. The congress dealt with the terms applicable to the by-products derived from mineral oils; the book contains three tables covering those derived from Pechelbronn petroleum, from benzoles and tars, and from the Autun shales, but more remains to be done, internationally, under this head. Several of the papers review actual plant producing or utilising the mineral or vegetable spirits and oils; among these we may mention the communication by Mr. E. Brillié on "Internal combustion engines for train haulage." The volume forms a most complete encyclopædia on the subject. It can be obtained from the above-mentioned journal, 49, Rue des Mathurins, Paris.

Superheated Steam at Sea.—In a paper read before the Institute of Marine Engineers, on September 18, Mr. J. Neill, B.Sc., gave some interesting examples of the savings effected in sea service by the use of superheated, in place of, saturated steam. As is well known, the reciprocator benefits even more by superheat than does the turbine, and in some of the cases mentioned by Mr. Neill the gains have proved very substantial indeed. In one instance quoted, two sister ships were built with identical machinery, save that in the one case superheaters were fitted and in the other not. Averaged over five years' sea service, the ship with the superheater showed a fuel saving of 14 per cent. In another case quoted, viz., a passenger ship having engines indicating 7,000 h.p., the coal bill was 20 per cent. less with superheaters than without. Additional gains accrue from he reduction in the bunker space and consequent greater targo capacity.

THE LATE MR. J. B. EVERARD.

By the death of Mr. John Breedon Everard, which occurred at his residence, Woodville, Knighton Park-road, Leicester, on Wednesday, September 12, after a prolonged illness, Leicester lost a notable citizen of whom there are to be found memorials in the Derwent Valley Water Scheme and many of the outstanding structures in the town.

He was the second son of Mr. Breedon Everard, of Bardon Hill, Leicestershire, and was born on September 22, 1844. At the age of 18 he was articled to a firm of civil and mining engineers in South Yorkshire, and on the completion of his indentures he was appointed resident engineer on the section of the Midland Railway between Kentish Town and St. Pancras, which was then in process of construction. The work which Mr. Everard was in charge of also included the foundations and roof of St. Pancras station and the tunnel beneath it connecting with the Metropolitan Railway. When this was all completed in 1868 he started practice in Leicester as a civil engineer, and with his firm of Everard, Son and Pick, which now bears the name of Pick, Everard and Keay, he was associated in the design of many of the town's largest buildings, such as the Cattle Market, the Royal Infirmary, the Technical and Art Schools, and the Leicestershire and Rutland Asylum at Narborough. He was also engineering adviser to the quarries at Bardon Hill, Markfield and Shepshed.

Mr. Everard did valuable work for Leicester in connection with the city's water supply. His first efforts in this direction were made in 1885, when he sought means to obtain an increase of the available supplies. He later designed and carried out the works of the Swithland Reservoir, and was responsible for many improvements by additions to the then existing plant. In 1898 he prepared a plan for the acquisition of the Derwent Valley water, and when the necessary Parliamentary powers were obtained to form the Derwent Valley Water Board, he undertook the Leicester portion of the scheme, that is, from Sawley to Hallgates.

Mr. Everard was a member of the Institution of Civil Engineers and of the Mining Institute, and was a Fellow of the Surveyors Institute, the Geological Society and the Royal Institute of British Architects.

PETERBOROUGH ELECTRICITY SUPPLY.

AN interesting piece of work has just been completed at Peterborough with the formal opening of the reconstructed electric power station. As in many other places, the original electrical installation of the city was on the three-wire direct-current system, the initial plant, which was put in operation in 1900, consisting of two 60 kw. Willans-G.E. multipolar machines and two Lancashire boilers, together with a battery, balancer, booster and the necessary auxiliaries. The plant was gradually extended, until in 1919 the installed capacity was 1,340 kw. In that year, owing to the growing load, it was decided to modernise and extend the plant and change over the whole generation to three-phase alternating at 6,600 volts, 50 cycles, installing converting plant to deal with the old direct-current area. An application was also made for an extended area of supply, and such an order was granted to the Corporation in December, 1922, which authorised supply in an area 39 times greater than that covered by the original order. The new area and the reconstruction have made the Peterborough station an important unit in the growing modernisation of electricity supply throughout the country.

The extension and modernisation of the station has particular interest in that no attempt has been made to retain the old plant, and the new generating units have been placed in the same station and in the position previously occupied by the direct-current machinery, so that the plant now exists as an entirely modern and uniform station. Mr. W. M. Selvey acted as consulting engineer for the alterations, and the English Electric Company, of Queen's House, Kingsway, W.C.2, acted as main contractors for the whole of the new machinery and works. The new generating plant consists of one 1,000 kw. and two 3,000 kw. turbo-alternators, one 500 kw. and two 750 k.w. rotary converters and two 100 kw. motor-generators for tramway supply, with the necessary switchgear. The whole of this material is of English Electric manufacture, except one of the turbines and the circulating pumps, which were supplied by Messrs. Peter Brotherhood, Limited, and the condensing plants for the other turbines, which were supplied by Messrs. Cole, Marchant and Morley. These firms acted as sub-contractors to the English Electric Co. The original foundations of the engine room gave considerable trouble owing to the nature of the site, and ultimately the whole area was excavated to a depth of 14 ft. and an arched concrete raft was constructed to carry the whole of the buildings. Apparently an excellent job was made, as the foundations have been found quite satisfactory for the new plant which has been placed on the old raft. The operating floor has been raised 8 ft. above the old floor to give sufficient head room for the condensing plant. This arrangement has necessitated lifting the roof of the station through 6 ft., while steel stanchions have been fixed to the inside of the engine room wall to carry the rails from the new and heavier crane which has been installed.

The old boiler house, which at the time of the alteration contained six Lancashire boilers, did not lend itself to alteration to suit the new water tube boilers and a new house has been built. This contains two 25,000 lb. Spearing boilers with chain-grate stokers, and two similar boilers equipped for burning pulverised fuel, unit type pulverisers being used. The new boiler house is built on the site of the old, and the Lancashire boilers were operated for a considerable time in the open air during the erection of the first part of the new house. The change-over from the old steam range to the new boiler plant was carried out without shutting down the station. A similar piece of work was carried out in connection with the direct-current switchgear which was moved from the north to the west end of the building without interruption of continuity of supply. An automatic telpher apparatus with a capacity of 15 tons an hour has been installed in connection with the new boiler plant to transport coal from the dumps alongside the L. & N.E. Railway siding and deliver it to the bunkers which feed the mechanical stokers and pulverisers. New work carried out outside the power station consists of 9·15 miles of E.H.T. feeders and substation equipment on the premises of six large consumers. Two new substations have also been built in new areas for low tension alternating current distribution. The cables were supplied by Callenders Cable and Construction Company.

THE USE OF THE SMALL CONVERTER FOR THE PRODUCTION OF LARGE STEEL CASTINGS.*

Comm. Ing. C. VANZETTI, C.B.E. (Milan).

THE Steel Foundry of Milan, established in 1888 for the production of light steel castings with the small Robert converter, worked for several years with no other apparatus. About 1895, when the increased number of orders made continuous working possible, two small open-hearth furnaces of 3 tons and 4 tons respectively were installed, and later a third one of 7 tons. In 1910 electric furnaces were introduced—at first three Stassano furnaces of 1 ton each; afterwards two Electro Metals furnaces of 3 tons to 3·5 tons were built. During the war several more electric furnaces of the latter type were installed. At present the foundry is served almost exclusively by Electro Metals furnaces, using a F.M.A. furnace (of our own design) for short periods when the Electro Metals furnaces are under repair.

In exceptional circumstances, for instance during the winter, when in Lombardy hydro-electric power fails, and it becomes necessary to use the more costly power derived from heat sources, one of the small open-hearth furnaces is started in addition.

As early as 1894 we began the production of large castings, using the converter alone. At the Milan works three Robert converters C, Fig. 1, of about 1 ton each, were installed, with two cupolas, E, each capable of melting 6 tons of pig-iron per hour. One of the three converters has never been in operation, and is held in reserve. There are two piston blowing engines, A and B, one driven by steam, the other by electricity, each capable of delivering 90 cub. m. of air per minute at a pressure of 40 cm. of mercury. One of these is in operation and the other in reserve.

In the first years of the operation of the plant, castings of about 2 tons maximum were produced, working with one converter only. Three successive heats were collected in the ladles, the first heat being teemed into a 1-ton ladle, and the second into a 3-ton ladle. When the third heat was ready, the first was tipped into the 3-ton ladle, and the 1-ton ladle was then brought again under the converter to receive the third heat. In 1894 it was believed we could accept the order for the two propeller shaft brackets for H.M.S. Marco Polo. Each casting weighed 6 tons net, or about 10 tons gross. To avoid the chance of running short in making the first one, it was calculated that 12 tons of molten metal would be necessary.

At that time the foundry did not possess a travelling crane of more than 6 tons capacity, so that it was necessary to devise a tank receiver mounted on two standards into which to teem the steel. The casting of the first bracket was a complete success, insomuch that, for the second, it was decided to prepare only 8 tons of steel. The additional 2 tons necessary for the feeding head were blown afterwards and poured direct into the runner forming the feeding head. Two cupolas were kept in continuous operation, and two converters were worked alternately, the blowing engine having to run continuously.

The result was so satisfactory that the firm then did not hesitate to accept orders for much more important castings. Most of the stems, stern frames, and rudder frames of Italian merchant ships and ships of war were cast by the method described, which naturally in the thirty years of our experience has been perfected to a high degree.

On account of its convenience, the system in general has been retained to the present day. Recently, having to supply some large rings having an internal diameter of 1·50 m., an external diameter of 2·50 m., and 75 mm. thick, which had to be absolutely without the least defect, I preferred, rather than cast them singly, to cast them in the form of large tubes, weighing about 30 tons each, out of which the rings were turned in the lathe, and all were perfectly good. From every tube it was found possible to turn one ring more than had actually been provided for, on account of the small amount of pipe due to feeding with hot steel for some time after teeming. Some brief notes on the method of procedure may be given here.

The Robert Foundry consists of three bays, each 10 m. wide, as shown in Figs. 1 and 2. At the end of the central bay the two cupolas, E, are placed. The ladle for receiving the molten metal is run between the two cupolas, and when filled is lifted by a special windlass to a height sufficient to enable it to tip the metal into either one of two sheet iron troughs which can be slewed on a swivel. Through these troughs it flows into the converters marked C. These latter are tilted by motors, but hand gear is also provided. A travelling crane ranging the whole length of the bay brings the steel ladle into position to receive the charge from the converters, and pour it into the receivers marked F, 1 and 2 (Figs. 1 and 2), which are suitably placed in the foundry for pouring the contents direct into the mould. The third converter is kept hot and remains in readiness in case of accident.

It will be understood that it is necessary to have the metal very hot and to work very rapidly, other considerations of economy having to be sacrificed to these two conditions. On this account a higher proportion of pig-iron than of steel scrap must be charged into the cupola, the quantity of coke for melting is increased, and the converters besides are furnished with eight instead of five tuyeres. A higher air pressure is thus required for blowing the converters, and this increases the loss in blowing.

It is customary to send the first heats of each converter to the foundry for ordinary castings, then, when a sufficiently high temperature is reached, the filling of the receiver is begun.

The blowing of the converter is stopped on the complete disappearance of the flame, which corresponds to a carbon content of 0·07 per cent. to 0·08 per cent. The additions of ferro-silicon and ferro-manganese are made in the ladle after teeming from the converter. The carbon is brought up to the requisite amount, adding in the receiver, if occasion requires, the proper quantity of molten pig-iron taken from the cupolas.

The receivers are respectively of a capacity of 10 tons, 12 tons and 15 tons. They are constructed of iron plate in cylindrical form, with their axes horizontal. They turn on two trunnions, and are furnished at the two opposite ends with two openings, as shown in Fig. 3. These are lined with a thick layer of refractory brick. Several hours before melting begins, the receivers are adjusted as shown in Fig. 3, A, and to the lower opening *a* is applied a portable burner. For the last two years burners fed with heavy oil have been used. The products of combustion escape by the upper opening *b*. The heating up is continued for several hours, so that when the first charge from the converter is ready, and the receivers are turned up as shown in Fig. 3, B, the lining is heated to a white heat.

When the receivers have been charged with the necessary quantity of steel, as much slag as possible is run off and a pouring spout of special form is attached to opening *a*, having a bore of 50 mm.

Before proceeding to pour, the temperature of the bath is tested by an empirical, but practical, method. As is known, steel castings must be poured at the lowest temperature compatible with their dimensions. Before pouring, an iron washer about 12 mm. diameter is plunged quickly to a depth of about 6 in. in the metal in the receiver. If the steel is very hot, the piece will melt in a few seconds; if it is very cool, it will form a solid crust around the washer.

The foreman founder judges from the form and thickness of the disc how many seconds it should remain in the bath before melting. Three or four successive tests will sufficiently indicate the temperature of the bath. If it is rather low, pouring is proceeded with as quickly as possible, risking the formation of a skull in the receiver. If it is too high, the pouring is delayed until the temperature is judged to be correct. In general, as soon as the steel is poured into the receiver, the temperature is too high, and it is necessary to wait.

Some years ago, owing to an interruption in the electric current just when the receivers were three-quarters full, the work had to be stopped for three-quarters of an hour. There was a small skull in the receiver, but the casting came out perfect.

When the foreman founder gives the order, the receiver is tilted at top speed to prevent the outflow of any slag remaining, with the metal. If that occurs, one or two ladlesful from the electric furnace or open-hearth furnace are poured together into the funnel of the receiver, and generally the feeding of the casting through the runner is continued for some time.

Notwithstanding that the total loss of metal exceeds 20 per cent. and the converter is acid-lined, it has always been customary to use pig-iron and scrap exceptionally free from sulphur and phosphorus. Before the war, washed coke of Belgian origin, almost sulphur free, was always used in the cupola. Now, we have to be content with a less pure material, but we still obtain very satisfactory results, the products showing a tensile

* Abstract of a paper read at the meeting of the Iron and Steel Institute, Milan, on September 17, 1923.

SMALL CONVERTERS FOR PRODUCING HEAVY STEEL CASTINGS.

Fig. 1. ROBERT CONVERTER PLANT & AUXILIARY APPARATUS.

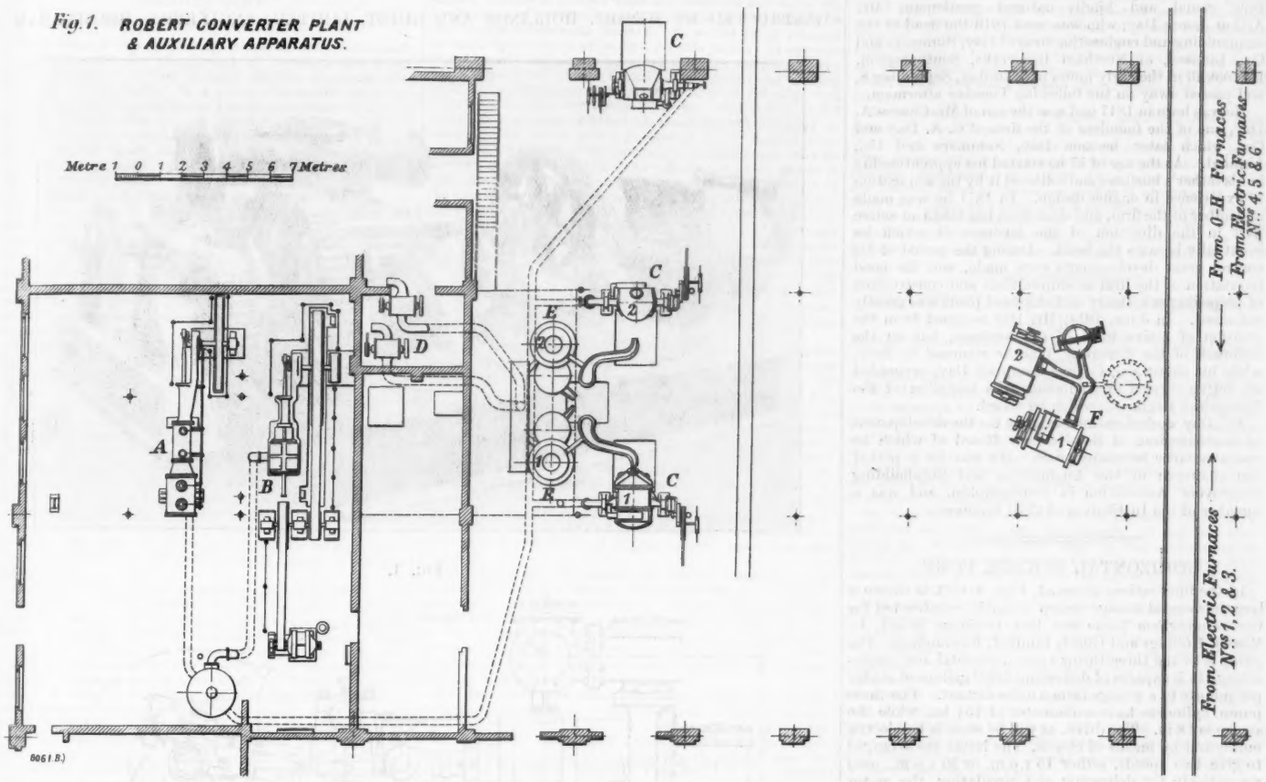


Fig. 2.

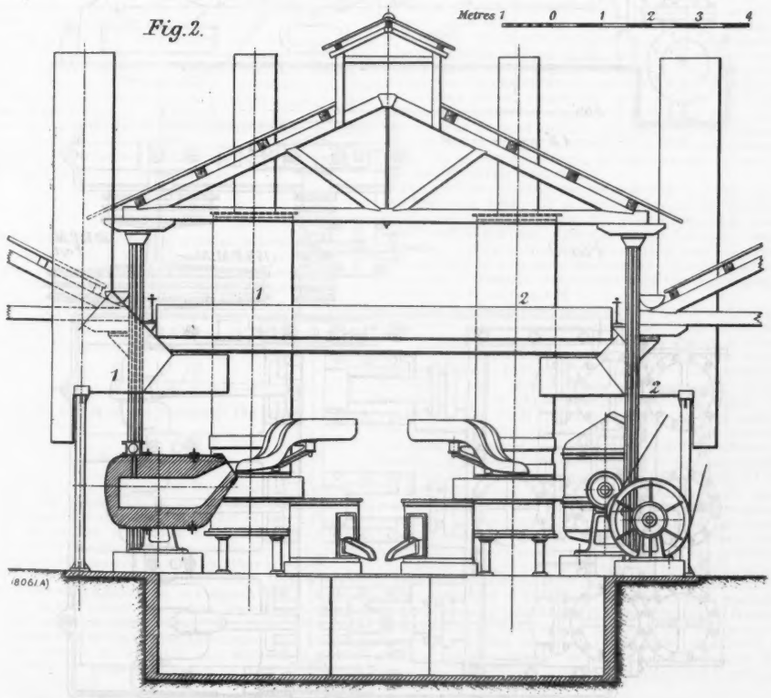
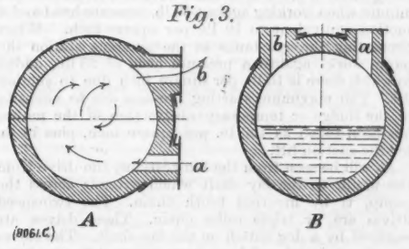


Fig. 3.



strength of from 45 kg. to 50 kg. (29 to 32 tons per square inch) with elongation equal to 20 per cent.

We trust that these notes describing briefly our method of working may be of some interest. Mr. Pourcel, honorary vice-president of the Iron and Steel Institute, who was for twenty years our consultant, has always taken a keen interest in our operations. Professor Howe, when in Italy, also came to Milan to witness the pouring of a casting, and took away with him several specimens.

The chemical composition and mechanical properties of steel improve after remaining a long time in the receiver. The steel as it comes from the converters contains considerable quantities of oxides and silicon in suspension. During the time it remains in the receiver these impurities separate out, partly by liquation and partly by the reactions produced by the manganese and silicon content in the steel.

The converter not only provides a means of obtaining at short intervals a very hot steel in small and frequent quantities for feeding the runner, but it reduces very considerably the volume and weight which it is necessary to give to the feeding head.

CONTRACTS FOR NEW ZEALAND RAILWAYS.—The Department of Overseas Trade, 35, Old Queen-street, S.W. 1, announces that it has received specifications and drawings relative to a call for tenders for the construction of certain sections of the East Coast Main Trunk Railway, New Zealand. The documents may be inspected up till October 31, at the offices of the Department.

HEAVY LOCOMOTIVES FOR INDIA.—Messrs. William Beardmore and Co., Limited, whose locomotive works at Dalmuir have quite a fair amount of work in hand for the Burma Railway and Indian State Railways, have recently booked another order for the North-Western Railway of the latter system. This is for five standard passenger superheater 4-6-0 type engines and six-wheel tenders, similar to the 30 already in hand for the Indian State Railways. These locomotives weigh over 120 tons in working order.

MANGANESE STEEL.—In a pamphlet recently published by the British Science Guild, of 6, John-street, Adelphi, Sir Robert Hadfield gives a popular description of the discovery of manganese steel and of the special properties which have rendered this, the first of the alloy steels, so exceedingly valuable for use in cases where great resistance to abrasion is required. Familiar applications are its use for tramway points and for the jaws of crushers, but perhaps the application which will have the widest appeal to those hitherto unacquainted with the facts is the use of this metal for the helmets with which our men were provided during the war. Owing to the peculiar properties of this alloy, the helmets made from it had much greater resistance, weight for weight, than those made from other varieties of steel. In all, it appears, that rather over 1,000,000 tons of this alloy have been produced since its first discovery. Although it originated here, the first large-scale applications of it were made in America.

THE LATE MR. A. J. DAY.

We very much regret to announce the death of that very genial and kindly natured gentleman, Mr. Arthur James Day, who was until 1918 the head of the shipbuilding and engineering firm of Day, Summers and Co., Limited, of Northam Ironworks, Southampton. He took ill in the early hours of Saturday, September 8, and passed away on the following Tuesday afternoon.

He was born in 1847 and was the son of Mr. Charles A. Day, one of the founders of the firm of C. A. Day and Co., which later became Day, Summers and Co., Limited. At the age of 17 he started his apprenticeship in his father's business and followed it by the acquisition of experience in engine design. In 1871 he was made a member of the firm, and since then has taken an active part in the direction of the business of which he eventually became the head. During the period of his control great developments were made, and the good reputation of the firm as shipbuilders and constructors of propelling machinery and shipyard plant was greatly enhanced. In June, 1914, Mr. Day resigned from the position of active head of the business, but on the outbreak of the European War he returned to duty, while his eldest son, Colonel Campbell Day, proceeded on active service in command of a battalion of the Hampshire Regiment, which he raised.

Mr. Day worked enthusiastically for the development of Southampton, of the Harbour Board of which he was a member for many years. He was for a period the chairman of the Engineering and Shipbuilding Employers' Association in Southampton, and was a member of the Institution of Civil Engineers.

HORIZONTAL SEWAGE PUMP.

In the illustrations annexed, Figs. 1 to 3, is shown a large horizontal sewage pump recently constructed for the Birmingham Tame and Rea Drainage Board, by Messrs. Hollings and Guest, Limited, Birmingham. The pump is of the three-throw type, horizontal and single-acting. It is capable of delivering 1,000 gallons of sludge per minute to a sewage farm 5 miles distant. The three pump cylinders have a diameter of 15½ in., while the stroke is 18 in. The drive, as will be seen, is by electric motor and by means of chains. The latter are arranged to give two speeds, either 15 r.p.m. or 30 r.p.m., used respectively for delivering and circulating, the motor being of 60 h.p. The normal duty is 500 gallons per minute when working against 50 lb. pressure head and a suction equivalent to 10 lb. per square inch. When circulating through tanks at the pumping station the pump works against a pressure head of 25 lb., added to which there is 10 lb. per square inch due to suction lift. The maximum starting pressure due to viscosity of the sludge or temporary obstruction of the mains, has been taken as 100 lb. per square inch, plus 14 lb. for the suction lift.

As will be seen from the illustrations, the drive from the motor to the lay shaft which extends across the pump, is by inverted tooth chain. The two-speed drives are by triple roller chain. These drives are engaged by a dog clutch on the lay shaft. The valves are of gun-metal and have been designed to give large unobstructed passages for the sludge being pumped. The openings through the valves are 8 in. in diameter, while the suction and delivery pipes are 10 in. in diameter. Although single-acting, the pump is designed with plungers of the piston type, the piston rods passing through glands in the ordinary way. The inner ends of the cylinders are vented and drained, so avoiding any trouble in the pump-house from leakage past the piston. The motor is of the pipe-ventilating type, fitted with slip rings, suitable for three-phase current at 50 cycles and 220 volts.

CHILEAN IRON AND STEEL.—The report for the 1st inst., issued by the Anglo-South American Bank, Limited, states that the Ministry of Industry and Public Works is reported to have drawn up a Bill, which has been approved by the President, for asking Congress to sanction the payment of subsidies to new companies manufacturing iron and steel from Chilean raw materials. The measure proposes that, for a period of ten years, new iron and steel companies shall be paid a premium of 15 dols. gold per ton of ingot iron, and the same premium per ton of steel produced, up to a total annual output of 30,000 tons of iron or steel produced during the first two years; up to 40,000 tons during the third and fourth years; and up to 50,000 tons during the remaining six years. An additional premium of 5 dols. gold per ton of ingot iron or steel produced up to a total of 20,000 tons, and sold outside Chile, would be paid during a period of 20 years. If several firms combine to reach the output above mentioned, the distribution of the premium would be effected in proportion to the actual production and exportation. The necessary funds for the payment of the premium on production would be obtained from the revenue derived from the mining tax, while the export premiums would be met out of the taxes on the exportation of iron ore. The rate of exchange being normally 13·33 dols. to the £, the subsidies proposed appear to be high.

HORIZONTAL SEWAGE PUMP.

CONSTRUCTED BY MESSRS. HOLLINGS AND GUEST, LIMITED, ENGINEERS, BIRMINGHAM.

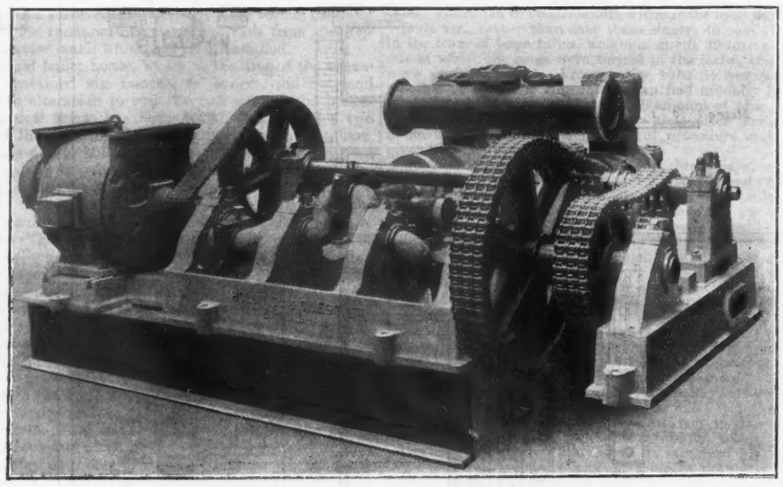


FIG. 1.

Fig. 2.

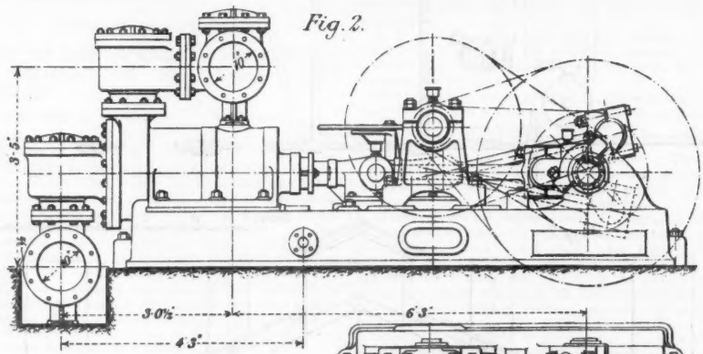
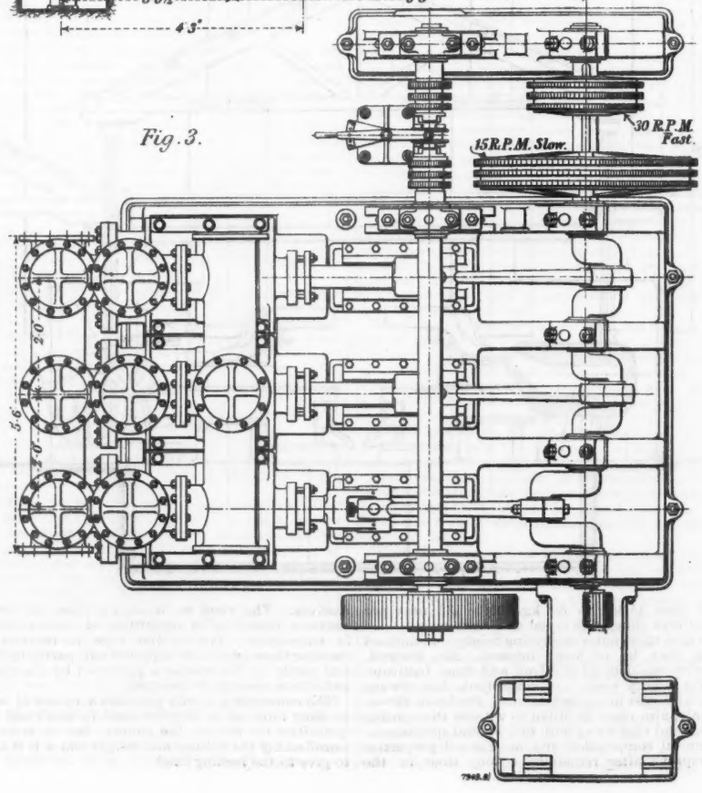


Fig. 3.



COHESION FROM THE ENGINEERING STANDPOINT.*

By A. A. GRIFFITH, D.Eng.

THE branch of engineering which is most intimately concerned with the phenomena of cohesion and intermolecular force is the science of the elasticity and strength of materials. In a piece of material under no stress the resultant cohesive forces are balanced by the kinetic reaction due to the thermal vibrations. If the molecular configuration be altered slightly, this equilibrium will be upset, so that the new configuration can only be maintained by the application of appropriate stresses to the piece. On the removal of these stresses the original configuration will be restored; hence we have the property of elasticity, or capacity to resist deformation, on which the technical usefulness of structural materials depends. Naturally the elastic deformation is not unlimited. Thus, under the action of a tensile stress, the cohesive resistance to extension reaches a maximum at a particular value of the extension, and thereafter decreases. Hence, if the corresponding critical stress be exceeded, fracture by direct atomic separation must ensue. Thus, it would appear that the correlation of data on the breaking strengths of materials, with the known magnitude of the cohesive forces obtained by physical methods, should be a comparatively simple matter.

Actually, this is far from being the case. One reason for this is that the majority of structural metals are ductile, so that under ordinary stress-systems, which almost invariably comprise shearing stresses, the primary failure does not involve atomic separation at all, but is a failure in shear. Now, the mode of collapse of a space lattice in shear is a subject which appears to have been studied very little by physicists, so that practically no information on the matter, from the standpoint of molecular cohesion, is at present available to engineers. Even the nature of the action which occurs is not yet established.

In the case of certain materials, *e.g.*, glass, stone and hard steel, which exhibit brittle fractures running perpendicular to the direction of the greatest tensile stress, it appears that the shearing type of failure does not occur. Hence the stress necessary for fracture should be determined by the magnitude of the maximum resultant cohesive forces normal to the fracture. As a matter of fact, it is found, when comparison is made, that a large discrepancy apparently exists, the observed tensile strengths being only a small fraction of the molecular tenacity. Thus, in the case of dead hard carbon tool steel, the applied tensile stress necessary for fracture is only about 160,000 lb. per square inch, while the cohesive forces to be overcome in order that fracture may occur correspond with a tensile stress of the order of 4,700,000 lb. per square inch.

The reason for this discrepancy was discussed in a paper published in 1920.† It was shown that the difficulty could be resolved by the hypothesis that the material contained minute cracks or flaws. According to this theory fracture was due to the very severe concentration of stress at the corners of the cracks.

In the course of the work an expression for the strength of a thin flat plate, containing a small crack having the sharpest possible corners, was worked out theoretically. The strength found by this method is:—

$$P = \sqrt{\frac{2ET}{\pi C}}$$

where P is the tensile stress at a distance from the crack, and normal to it, E is Young's modulus, T is the surface tension of the material, and 2 C is the length of the crack. This expression differs from the one given in the paper owing to the application of the correction referred to in the footnote to the latter.

The ratio of the maximum stress, F, in the corner of the crack, to the stress P is approximately—

$$\frac{F}{P} = 2\sqrt{\frac{C}{\rho}}$$

where ρ is the radius of the corners of the crack. Hence F is given by—

$$F = 2\sqrt{\frac{2ET}{\pi\rho}}$$

If a value for ρ is assumed this expression gives a measure of the magnitude of the force of cohesion. It is most probable that ρ is of the order of the molecular spacing, and, in fact, a value of ρ equal to two or three times the molecular spacing gives values for F about the same as those obtained indirectly by other methods.

In the cases of glass and fused silica this cohesive tenacity is about 1,600,000 lb. per square inch. As was mentioned in the paper referred to above, and also in the Report of the Complex Stress Committee‡ presented at the last meeting of the British Association, it is possible to prepare glass in an unstable, and silica in a stable, form in which a large proportion of this theoretical tenacity is possessed.

There is another type of fracture obtained with brittle materials, in which the cracks run obliquely to the principal stresses. These are usually termed by engineers "shearing" fractures, the best known case being the crushing fracture obtained by simple compression. Now, from the molecular cohesion standpoint, it is very difficult to conceive how true shearing fracture can take place. The essential condition for the formation of a crack would seem to be the existence, normal to its surface, of a tensile stress sufficiently great to overcome the cohesive forces, whence it follows that any fracture following the application of a shearing stress should be due simply to the tensile component thereof. It would be of interest to have the views of physicists on this point. It appears that this difficulty may be removed with the help of the same hypothesis as was found to be effective in dealing with the discrepancy between the force of cohesion and observed tensile strengths. If we consider a solid containing a large number of small cracks oriented at random, the piece being subjected to a simple compression, we find that the periphery of each crack may be divided into four sections, in which the edge stress is alternately tensile and compressive; further, in some of the cracks running obliquely to the applied compressive stress, the maximum concentration of tensile stress is comparable with, though less than, the maximum concentration which would occur in the normal cracks if the piece were to be subjected to a tensile instead of a compressive load. Hence the material would break obliquely under a compressive stress of the same order as, but larger than, the observed tensile breaking stress. The fracture, however, would be a tensile, not a shear, fracture.

In the two dimensional cases (a thin plate pierced with a large number of small cracks), the numerical values of the stress concentrations in the two cases may be worked out with the help of Inglis' solution for the stresses in a cracked plate*; thence, on the assumption that fracture is conditioned by the existence of a specific tensile stress at the edges of the most favourably disposed cracks, the theoretical ratio of the tensile and crushing strengths may be evaluated. It is found thus, assuming the existence of the very sharp cracks necessary to account for the extremely low experimental tensile strengths usually found, that the crushing strength should be eight times the tensile strength. Variations in this ratio would occur if initial stresses existed in the material.

The calculated ratio agrees very well with experimental values obtained for brittle materials such as stone and cast iron; in other cases (*e.g.*, carbon tool steel) the divergence is not greater than could be accounted for by the existence of initial stresses, or by differences between the theoretical values for the two and three dimensional cases. To this extent, therefore, it appears that the suggested theory is confirmed.

We may now give some further consideration to the technically much more important type of elastic breakdown which occurs in ductile metals. If a sufficiently great tensile or other appropriate load be applied to a bar of such material, the action which ensues may be considered in three stages. The first is the almost instantaneous stage of elastic straining, which is comparatively well understood in relation to molecular forces. The third is the stage of molecular separation or fracture, which occurs almost, if not quite, as quickly. The intermediate stage is the stage of plastic or ductile straining, which invariably takes a relatively long time. About the fundamental nature of this latter action we at present know practically nothing, and until this intervening barrier of mystery is broken down, it would appear that it must remain impossible to correlate the phenomena of ductile fractures with the known facts of cohesion, as has been done, to some extent at least, in the case of brittle fractures.

The problem which awaits solution may be put in the following form. If a metallic crystal be subjected to a shear strain, what is the greatest possible elastic strain and, in the case of greater strains, by what changes in atomic configuration and orientation does the crystal adjust itself to the new conditions? Further, what is the state of stress in the crystal after the completion of the process of adjustment?

In the course of some work on overstrain and fatigue, the present author has constructed, in collaboration with Mr. B. Lockspeiser, of Farnborough, a theory of plastic strain (not yet published) which may have some bearing on the foregoing problem. In this theory the conclusion is reached that plastic strain is simply the external manifestation of phase changes occurring within the material. The term "phase change" is here used in the ordinary sense of the production of new material chemically the same as, but physically different from, its parent. The view that phase changes occur during plastic straining is, of course, not new. The novelty of the theory arises from the fact that deductions are made regarding the number and nature of the distinct phases concerned in the action. The equilibrium of the system is investigated by the application of Gibbs' Phase Rule, but in this connection it is to be noted that the possibility that phase changes can be induced by the application of a pure shear stress renders it necessary to take account of five "degrees of freedom" associated with variation of shear stress, in addition to the usual degrees of freedom associated with variation of temperature and pressure. According to the modified phase rule, it should be possible for five distinct crystalline modifications of a given pure metal to co-exist under appropriate conditions of stress and temperature.

It is this latter conclusion which makes the foregoing theory of interest in connection with the present discussion. Questions which occur at once are, firstly, whether it is likely on physical grounds that phase changes can occur as a result of the application of a shear stress, and, secondly, whether it can be said, in the light of existing knowledge regarding the nature of inter-atomic forces, how many distinct phases of a given pure substance are theoretically possible.

At first sight, it would appear that phase changes must involve changes in either the configuration or the relative orientation of the atoms. Changes of the former type should be immediately discoverable by means of X-ray examination of overstrained and unstrained material, but the known method of phase transformation, viz., by the application of shear stress, rather suggests that changes in orientation are the more probable. Even so, the question still arises as to whether such changes could occur without a measurable alteration in the space lattice.

Until solutions to the foregoing problems have been found, it would appear to be valueless to enter on any discussion of the mechanism of the fractures which occur after plastic straining (in which category we may include fatigue fractures). Existing knowledge relative to mechanical tests of materials makes it abundantly clear that the types, and even the directions, of the fractures are so closely related to the nature and extent of the previous straining, that any such discussion at the present time would be almost purely speculative.

* Contribution to a joint Discussion of Sections A, B and G of the British Association at Liverpool, September 13, 1923.

† Phil. Trans. A. vol. 221, pp. 163-198.

‡ See ENGINEERING, vol. cxiv, page 209.

* Proc. Inst. Naval Architects, March 14, 1913. ENGINEERING, vol. xcv, page 415.

TRANSPORT AND ITS INDEBTEDNESS TO SCIENCE.*

Address by SIR HENRY FOWLER, K.B.E., *President of the Section.*

I FEEL that it is right that the Engineering Section of the Association here in Liverpool should devote one of its sessions to the subject of traction. There is no city in the Empire, or in the world, which is so dependent on traction in one way or the other as the one in which we are meeting to-day, and I can also say without fear of contradiction that there is no city in the world which has acted as so great a pioneer in traction development as this one on the Mersey.

Its very birth was caused by the physical features it presented at a time when the estuary of the Dee was silting up, whilst whatever may be the derivation of the first portion of its name, there is no question but that the latter portion refers to the advantages it offered for water transport.

It is not necessary, nor am I qualified, to speak of the development of the "pool" into the port which means so much to Liverpool at the present day, but there are other methods of transport in which it has played an important part that I should like to mention.

As early as 1777 Liverpool realised the necessity and advantages of easy and cheap transport, and the canal from Liverpool to the Trent was constructed at that date, having a length of 96 miles. This joined the Trent at Shardlow, not far from Nottingham, and it has recently been suggested the river should be canalised from there to the sea on the East Coast.

More recently Liverpool has become connected with its sister city of Manchester by the Ship Canal, in the carrying out of which many interesting engineering problems were met and solved.

The better remembered event is, however, in connection with transport by rail. It was the construction of the Liverpool and Manchester Railway in 1829 and its immediate success that more than anything else impressed on the country the fact that a new system of traction was opening out unheard-of possibilities. It is not too much to say that the production of the "Rocket" for the trials at Rainhill in October, 1829, marked the first step in the practical commercial success of railways.

This, however, has not been the last association of the city in pioneer work on the rail in this country. In 1904 the Liverpool and Southport section of the Lancashire and Yorkshire Railway was electrified, this being the first inter-urban electric line in this country. The change was due to the enterprise and foresight of Mr. (Sir) John A. F. Aspinall, a distinguished son of Liverpool, and the directors of the Lancashire and Yorkshire Railway. The electrification of the line was preceded by exhaustive trials to determine the tractive force required to overcome the resistance on railways,† and with these trials I had the honour of being connected.

The other matter in which Liverpool has done pioneer work on traction is that of heavy motor traffic. From its inception in 1895 the Liverpool Self-propelled Traffic Association was specially connected with this method of transport. Under the presidency of the late Sir Alfred Jones, with the guidance of Dr. Hele Shaw and under the organising ability of its enthusiastic and energetic secretary, Mr. E. Shrapnell Smith, it organised and carried out trials of commercial vehicles in 1898, 1899 and 1901. In May, 1898, were carried out the first practical trials of these vehicles held in the country and I had the honour of being the observer of the first lorry to leave the yard. The Motor Car Act, of 1903, which allowed a practical weight for commercial road motor vehicles, was the result of a deputation of the Liverpool Self-propelled Traffic Association waiting on the President of the Local Government Board (the Right Hon. Walter Long, now Viscount Long) when he was on a visit to Liverpool.

I think I have said enough to justify the statement I made that it is fitting that one of our sessions here in this city of Liverpool should be devoted to the question of transport, and I wish to speak of its indebtedness to Science, and trust I may be able to show that, as with other branches of engineering, its progress is due to science, and, in concluding, speak of how it may repay, if inadequately, the debt under which it is placed.

We are perhaps too apt at the present time to forget the obligation which the world owes to transportation, so commonplace have the improved methods become.

* Address delivered before Section G of the British Association at Liverpool, September 14, 1923.

† See Mr. (Sir) J. A. F. Aspinall's paper on "Train Resistance," Proceedings of the Institution of Civil Engineers, vol. 147, 1901.

We are already forgetting the lesson that the submarine menace gave us on this matter during the war, and again looking upon the movement of matter from point to point as a commonplace occurrence. It has been said that effective transportation is one of the great aids to civilisation, but it must not be forgotten that all movement of material from place to place is economically waste as far as the dissipation of work is concerned. Problems of transportation have been solved more or less successfully in all ages, and some of them, such as the moving of the stone to Stonehenge, &c., still excite our wonder and admiration. Such works, and similar ones of much greater magnitude in the East, however, we feel as engineers could be accomplished by quite crude methods if there was unlimited labour available, and if time were of no consequence.

The transportation which aids civilisation is that which cuts down the wastage of power to a minimum and which reduces the time occupied in carrying this out. It is here that science has helped in times past, and will help increasingly in the future if we are to go forward. In no other branch is Telford's dictum that the science of engineering is "the art of directing the great sources of power in Nature for the use and convenience of man" so well exemplified, and this utilisation has been carried forward at ever increasing speed during the last hundred years.

If we take the definition of Science as "ordered knowledge of natural phenomena and of the relations between them," as given by W. C. D. Whetham in the *Encyclopædia Britannica*, we shall easily see how transportation has been dependent upon it.

It may be that some may not agree with this definition of "ordered knowledge of natural phenomena," but I feel that after thought it will be recognised that it covers very completely what we call Science. We are rather apt to confuse the knowledge with the means and apparatus applied in getting it. Recently I have read an article which called attention to the dependence of science upon engineering or mechanical achievement, but surely the accuracy we get, the lack of which was such a great drawback to the investigations of a century to a century and a half ago, is itself based upon "ordered knowledge."

Dealing with transport, it may be said roughly that it is mainly dependent upon three things—the method of propulsion, the material available for use, and the path over which traction takes place. I cannot deal fully even with one of these, and I propose to confine my remarks to the first two, which are the ones I am best acquainted with.

It may be said that advance in traction really became rapid when methods of propulsion other than those of animals and the force of the wind became available. The greatest step forward—wonderful as some of the achievements of aeronautics have been of recent years—came with the development of the steam engine.

Like most great achievements in the world, it was not a lucky and sudden discovery of one individual, although here as elsewhere we associate the work with the name of one man especially. This has usually been the case, and without wishing to detract from the work of the individuals who are fortunate enough to utilise the ordered knowledge available to the practical use of man, one must not forget the labours of those who have sought out that knowledge and have given it freely to the world, thus placing it at the disposal of the one whose imagination and creative faculty were great enough to see how it could be utilised in the service of man.

The first attempt at traction by using a steam engine was a failure because of the lack of this knowledge. I refer to the work of Jonathan Hulls and his attempt in 1736–7 to apply one to the propulsion of a boat on the River Avon in Worcestershire. He failed because of the lack of that knowledge, although undoubtedly he possessed the necessary imagination.

Although James Watt is not directly associated with traction, it was his application of science to practical use that finally gave the greatest impulse to transportation that it has ever had. No advance had taken place to Newcomen's engine of 1720 until Watt's work of 1769. His knowledge of Black's work at Glasgow on the latent heat of steam and his own experiments with the Newcomen model led to the success of his improvements of the steam engine. His scientific knowledge is clearly shown in his patents and publications, for he dealt with steam jacketing in 1769, with expansive working in 1782, and he devised his parallel motion in 1784. His direct connection with transport includes the reference to a steam carriage and a screw propeller in 1784, whilst the firm of Boulton and Watt corresponded with Fulton for a period extending from 1794 to 1805.

Although Cugnot in 1770 and Murdoch in 1786 had made models of vehicles propelled by steam, it was Richard Trevithick with his steam carriage in 1801 and 1803 and ill-fated railway in 1804 who first showed the practical application which could be made. It is probable that the engine which his assistant, Steel, took to the wagon-way at Wylam in 1805 turned the thoughts of George Stephenson to the work that has meant so much for us. No one can read the early life of the father of railways without appreciating that he was from young manhood a searcher after scientific knowledge. Doubtless he owed much to the friendship of Sir William Fairbairn, the President of our Association in 1861. The advances he gave to the world of transport were all due to his practical application of the knowledge he had obtained himself or had learned from others. It is so often thought that because the early inventors and engineers of the beginning of last century had not received what we now call a scientific education that they were not in any sense of the term men of science. It must be remembered that at that time the knowledge of natural phenomena was very limited, and it was possible to know much more easily all the information available on a subject than at the present day, when we have such a mass of miscellaneous information to hand on every conceivable subject. It was ordered knowledge which led Stephenson to adopt the blast-pipe of Trevithick. It was the desirability of obtaining ordered knowledge that caused him to carry out those experiments which showed to him the advantages of using rails, and it was the scientific appreciation of the necessity of increased heating surface that made him adopt the suggestion of using tubes through the water space in the boiler of the "Rocket." His appreciation of the advantages of science was shown by his acceptance of the Presidency of the Mechanical Science Section (then as now Section G) of our Association in 1838. It is interesting to note that one of the earliest grants in Section G was for a constant indicator (for locomotives) and dynamometric instruments in 1842–43, whilst Stephenson was still alive. Let me remind you of his ready grasp of the application of a known principle to a different object by the story of the invention of the steam whistle. On the Leicester and Swannington Railway, which followed the Liverpool and Manchester, one of the Newcastle locomotive drivers—R. Weatherburn—at a level crossing ran into the cart belonging to an old lady, destroying her eggs and butter. Upon his return to Leicester, and reporting this to Stephenson, he was at once told to go down the town to a trumpet-maker and get him to make a trumpet which could be blown by steam. None but a mind in which the knowledge of natural phenomena was very carefully ordered could have so readily solved such a problem.

From the time of Stephenson the progress in propulsion on rails by steam locomotives was steady if slow. The investigations for a long while were largely confined to the question of expansion and condensation, and although the results attained were noteworthy in the case of steamships, on the rail—to which for the moment I will confine myself—there was little advance in the principle of propulsion, but, as I shall show later, the improvements in materials allowed a steady growth in power and size. Although work was done by compounding and using higher pressures, the greatest advance has come to steam locomotives by the use of superheated steam. This was no new thing, for Papin in 1705 seemed to have an appreciation of its value. As pressures and the resultant temperatures increased there came difficulties with lubrication. With the increased use and knowledge of mineral lubricants Dr. Schmit was in 1895 able to devise methods of using superheated steam which have been of the greatest use to transport and to the community.

The progress of transport on the rail has latterly strongly followed other lines, and I must for a few minutes go back again to the development of the use of steam in a turbine in order to speak of the subject of electric traction.

In spite of the fact that the idea of the utilisation of steam for giving rotary motion is old, its commercial adaptation in the turbine is modern. Rarely, if ever, has there been such a direct and instantaneous application of science to practice. We are too close at present to the matter to realise what a change has taken place in the world owing to the introduction of the steam turbine.

If we think for a moment we shall realise what a change has come over our lives, not only in an engineering but in a general sense, since the end of last century. It has truly been said that this is very largely due to an Italian experimenting with Hertz waves, to numberless young men lying on their backs on muddy roads under motor cars, and not least to a young Irish engineer who revolutionised transport.

One realises the work done by De Laval, Curtiss, Rateau, and the brothers Ljungstrom, but the name which will always be associated with the steam turbine as firmly as that of James Watt is with the inception of the steam engine is that of Sir Charles A. Parsons, our President for the meeting of 1919 at Bournemouth. The success of his work is due to his application of scientific principles to the many points of the turbine and its accessories. Apart from its application to marine work, it is the turbine which has made possible the economical production of electrical energy, which is doing so much, and will do so much more in the future, for rail transport. To-day it may be said, as it often has been, that there are no mechanical or electrical difficulties in the electrification of railways, the only difficulties being financial ones although one could hope that the induction troubles could be overcome by a cheaper method than at present available.

It is impossible here to trace the development of electrical science from the experiments described by Gilbert in 1600 to the equipment of electric locomotives on the railways of Switzerland and the United States of America. If we were able to trace this development we should see that it has been not only a gradual but a continuous and ordered increase of knowledge of natural phenomena. One must mention, however, what a change electrical traction by train and tube has made to our town life. It has rendered our large towns possible and given a chance to millions of our workers of a wider outlook on life and the opportunity of living amongst healthier and more pleasant surroundings. This, as just stated, is not the result of a sudden discovery of some fundamental principle, but to a studied advance, step by step from very elementary knowledge to the information we have available and at our disposal to-day. This is very largely the result of endless laboratory research and experiment.

The last method of propulsion that I can deal with is that by means of the internal-combustion engine. This, as we almost universally have it to-day, is the result of the cycle adopted by N. A. Otto in his gas engine in 1876. Here again the engines we have to-day are the result of careful and studied investigation. It may be truly said that the advance made has been so much more rapid than in the case of the steam engine and electrical machinery because of the more advanced state of scientific knowledge, and it furnishes an example of the assistance which this gives to progress.

In relation to transport the work has proceeded on two distinct lines, the Daimler and the Diesel engines. In 1885 Gottlieb Daimler produced the engine that is associated with his name, and which utilises a light spirit which supplies a carburetted air for the explosive mixture for the cylinder. The development of this engine has itself proceeded in two directions. In the one it has been made very much more flexible and silent in its adaptation to motor car work, whilst in the other the great desideratum has been lightness, and in association with the improvements in the necessary materials has rendered possible the aeroplane as we have it to-day. In both cases the development to the degree reached has been due to a careful study primarily of the pressures, compression, and composition of the mixture.

The Diesel engine was invented in 1894 by Rudolph Diesel, and consists of the injection of oil or pulverised fuel into the engine cylinder. Its development has taken place both on the four- and two-stroke cycle, and although considerable progress has been made with land engines, it has chiefly been used for marine transport.

The internal-combustion engine has not been largely used for rail transport owing to its comparatively high cost of fuel per horse-power and its lack of flexibility. The latter is particularly the case when one remembers the high torque which is so desirable, and which can be attained in both the steam and electric locomotives in starting.

Throughout these remarks on methods of propulsion I have dealt with the points connecting them with rail transport as they occurred, as this is not only the method with which I am most familiar, but is the oldest means of using mechanical power. I must, however, say a few words as regards transport by sea, road, and air in connection with methods of propulsion.

I have already spoken of the early efforts of Hulls, and it was only natural that the work of Watt on land should be followed by application of the new power available to propulsion on the water. Although the growth after the work of Symington, Fulton, and Bell may have seemed to be slow, it was continuous, and constant experiments and research were made both in marine engines and in their application. Saving of fuel has played a much more important part here than with the locomotive, whilst more space being available and greater power required, the advantages of the expansion of steam were rendered more imperative and had greater scope than in the other long-established method of mechanical transport. The great advance came with the turbine, and it is interesting to notice that whereas in early days engines were geared up, most of them now are geared down to the screw. Scientific methods have been applied to all those details of measurement and experiment that have led to transport by sea being carried on at increased speed and with decreased cost per ton carried. The application of liquid fuel and the introduction of Diesel engines, both with the object of increasing the space available for cargo, have been carried out on true scientific lines.

Of transport by road it may be said that its commercial inception came at a time when scientific knowledge was well advanced, and its progress was in consequence more rapid. It must not be forgotten that in the fairly early part of last century considerable work was done on scientific lines with steam cars, only to be abandoned when legislation made its continuance impossible. The development of the motor car engine from the small unit of Daimler to the present car is undeniably due to the use of "ordered knowledge" of the gaseous mixture, of its ignition, of the fuel itself, and of the compression that should be employed. Here again we have a case of careful application of the principle developed with ever-increasing care until we get engines as noiseless, as efficient, as reliable, and as flexible as we have them to-day. It is a case, too, where the development is so recent that many of us can remember the scorn and distrust that this method of traction excited even here in this city that was so prominent in its inception twenty-five years ago.

Very much more could be said as to the indebtedness of aeronautics to science, but the fact that this indebtedness is so self-evident, as well as the question of space at my disposal to deal with a subject of such a size, make it impossible to attempt to do justice to this part of my subject. I will only speak of the aeroplane, and its development has been even more rapid than that of the motor car. I personally feel this when I remember that Mr. A. V. Roe was one of my students here in Lancashire in the 'nineties.

It was not until the development of the internal-combustion engine that the matter became a really practical one. The early work of Santos Dumont, Henry and Maurice Farman, Wilbur and Orville Wright, A. Vernon Roe, Cody, Rolls, Blériot, Paulhan, and others led to the close scientific consideration of the whole problem.

Step by step investigations have led towards the perfecting of this type of transport. In all cases the developments have followed careful scientific research. Amongst our fellow-countrymen the work of Rolls, Godden, Cody, Busk, Keith-Lucas, Hopkinson, Pinsent, and others has unfortunately been terminated by their deaths in the cause to which they were devoting their lives. In no other field has scientific work demanded so great a toll. This must be so when one is dealing with transport in such a medium as air. The work of others, such as—to name but a few—Bairstow, De Havilland, Sopwith, Barnwell, Handley Page, B. M. Jones and O'Gorman, has fortunately continued. The war was naturally a great incentive to the advancement of our knowledge of

aeronautics, and I feel proud that at Farnborough, at the Royal Aircraft Factory, I was allowed to be associated with such men as Aston, Dobson, Farren, Gibson, Green, Grinstead, Hill, Irving, Linderman, Thompson and McKinnon Wood.

These were scientific men working on scientific lines, and their work was put to full practical test at once. The mass of information collected and used has been immense. One cannot in any collection of names omit one to whom one must ever be grateful—Sir Richard Glazebrook, again a son of Liverpool, who not only as Director of the National Physical Laboratory, but also as chairman, under the presidency of Lord Rayleigh, of the Advisory Committee of Aeronautics, did so much toward the development of this method of transport.

It is impossible to touch more than in the lightest possible manner on the developments which have taken place in aeronautics due to scientific work. In the means of propulsion research has given an engine of such size and so light in weight per horse-power that what was a laboured struggle against the effects of gravity has changed into the ability to rise at considerably over 1,000 ft. per minute to heights where the rarefaction of the atmosphere renders it necessary for oxygen for breathing to be obtained artificially. The safety of flying as the result of the work of Busk has rendered the machines stable even in such a medium as the air. There is no greater instance of the indebtedness of transport to science than the rapidity with which the possibilities of transport by air have advanced. That the realities have not advanced at the same rate is due to financial reasons. As a rule we have a close relationship between these two, but in this instance owing to the demands of war this has not been the case, for we have the knowledge before we are financially able to use it to the greatest advantage.

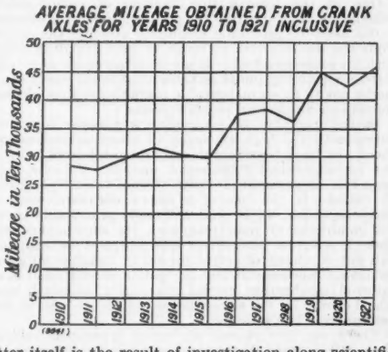
The other point I would deal with in some detail is the question of materials. Here we are dealing with a matter which has to be considered in an entirely different manner. We to-day have no basic metal or material which was not known when transport first turned to mechanical methods for assistance. The change which has come about has been as largely due to the advances made in metallurgy as to the inventions in mechanics that have led to the improvements in means of propulsion and in machinery. I am aware that neither of these would have been of any use were it not for the increase in facilities of production, but most certainly the scientific work of the metallurgist is one of the many points which, taken together, have caused the resultant progress. The early builders of steam engines were not only troubled through inability to get their engines machined properly, but also with the difficulties of obtaining suitable material for the parts they required. Steel has been known for thousands of years, but its rapid and economic production is of very recent growth. It has very truly been said that every great metallurgical discovery has led to a rapid advance in other directions. I will as before deal with the railway as an example. We can hardly appreciate at this date the conditions which existed from a metallurgical standpoint on our railways when our first meeting at Liverpool was held in 1837. Iron—made laboriously, heterogeneous in character and expensive of production, not only in money but, owing to the heavy character of the methods employed, detrimental to the very character of the workmen—was the only material available. Remember for a moment that this was not only the material employed for the various parts of the mechanism of the locomotive, but for the rails. However improved the methods of manufacture were, there could never have been a universal development of rail traction if it had depended upon material made in such a way. We are especially interested in the manner the growing demand was met, for it was at the Cheltenham Meeting of the Association in 1856 that Bessemer made public the invention he had already been working on for two years, and which was to insure a cheap method of production of a material so essential to transport. One should mention with Bessemer the name of Mushet, whose work helped so materially in getting rid of the red shortness which in the early days gave such trouble. We are apt at the present day, I am afraid, to somewhat belittle the work of Bessemer in view of the more improved methods now employed, but his name must for ever stand out as the one which made cheap transport possible. After the use of manganese in one form or the other as a deoxidiser and a "physic" for sulphur, there, however, still remained the baneful effect, due to phosphorous, which prevented the use of the ores of more general occurrence. There have been few more epoch-making announcements made at meetings of technical subjects—although this was not appreciated at the time by many of the audience—than S. G. Thomas's announcement of the discovery of the "basic" process, which he made at the meeting of the Iron and Steel Institute in March, 1878. I say advisedly that many did not appreciate the news, for an old friend of mine who was present was impressed by the earnestness of the remarks of Thomas and the little notice taken of the short statement made. His work, associated with that of his cousin, Gilchrist, was the result of close scientific research.

Another investigation which has given great results in transport has been the ever-growing use of alloy steels. For the scientific inception of those we owe a great debt to Sir Robert Hadfield, whose inventive genius and scientific mind are still active in that field he has made so particularly his own. His first investigations materially affect transport to-day. It is true that Mushet had previously worked on self-hardening tool steel containing tungsten, but the work was only carried out on a small scale. In 1882 Hadfield had produced manganese steel.* This is a most remarkable product with its great toughness, and is extensively used for railway and tramway crossings, where resistance to abrasion is of great value. This was the first of that very remarkable series of alloys about which I must say a few words, for they have made possible the motor car and the aeroplane as we have them to-day. Continuing his investigations, in 1889 Hadfield produced the compound of iron and silicon* known as low hysteresis steel. Indirectly this is of the greatest interest from a transport standpoint, as when used in transformers it not only reduces the hysteresis losses, but allows of a considerable saving in the weight of core material.

From these early uses of alloy steels there has grown up a large number of various alloys, many of which are of the very greatest use for various transport purposes. It is not too much to say that the modern aeroplane is the result of the material now at the designers' disposal both for the engine and for the structure itself. The strength of some of the chrome-nickel steels combined with their ductility is extraordinary, and is due not only to the composition of the metal, but to the results which have been obtained by patient scientific investigation relating to their heat-treatment. Taking one other example, one may quote the use of high chrome steel—for the early investigations into which we owe so much to Brearley, and to its later developments to Hadfield also—for the valves of aeronautical engines, subjected as they are to high temperatures. At one time it looked as if the advantages which follow high compression and its resultant high temperatures might be lost owing to the inability of ordinary steels to resist this heat, but the employment of 13 per cent. chrome steel allowed work in this direction to be continued. Not only the aeroplane but the motor car are, as has previously been said, the result of the work done on alloy steels.

It is not only with steels that we have been benefited so much from research. The case is as marked with light alloys, which have aluminium as a base. The

AVERAGE MILEAGE OBTAINED FROM CRANK AXLES FOR YEARS 1910 TO 1921 INCLUSIVE



latter itself is the result of investigation along scientific lines, and in aeronautical work particularly much has been done towards giving a metal both light and strong by the work of Walter Rosenhain, F. C. Lea, and others.

It may be said that all I have dealt with up to the present has been the result of special investigation, and that "ordered knowledge" is not of assistance to an everyday engineer such as myself. I may perhaps be forgiven if I refer to some personal work where the collection of that knowledge with the assistance of my colleagues, especially L. Archbutt and H. A. Treadgold, has been of great assistance to that large transport institution, the Midland Railway, with which we were so long associated. I have dealt briefly with the subject in a general way in a paper I read a little while ago before the Institution of Locomotive Engineers,† but would like to speak of it in more detail and in view of the fresh information that is now available. I would first speak of the results obtained with solid locomotive crank axles. Here we have a large mass of metal which in the rough state weighs about 40 cwt. It is forged from the ingot into a block about 25 in. by 18 in. in section, and this is then worked down at the two ends and in the middle to about 11 in. in diameter, the pieces of the original section of the block remaining being the throws which are twisted to an angle of 90 deg. to each other. A block about 1½ in. thick is slotted out of each web, and from these the tests to which the crank is subjected are taken. Sometimes a crank has to be taken out of service owing to the journal wearing down below a diameter at which it is judged safe for them to run, but more often flaws are developed which, however, are progressive, and with ordinary examination can be detected before any risk is taken in running. A crank axle is an expensive portion of a locomotive, and its replacement is not only costly but takes a considerable amount of time, as the driving-wheels have to be removed and replaced. These considerations have led us to give a good deal of attention to this piece of mechanism on what we believe to be scientific lines. Careful note has been taken not only of the mechanical tests made on the portion removed from the throws, but of the microstructure of the metal itself. The first question which rises in our mind is why the cranks develop flaws at all. It is, of course, known that with ordinary structures one is able to calculate the stresses in them, but this is not so with a locomotive crank axle. Not only is it being subjected to the stresses set up by revolving it while it is loaded with the weight of a portion of the locomotive on its axle-bearings and by the steam pressure on the pistons transmitted to the crank-pins, but it has to withstand the shocks set up by its running on the rails, which cannot be calculated. These include the pressure set up on the edge of the wheels when entering a curve at a speed other than that which the super-elevation is allowed for, running over uneven rail joints and crossings, and also what I believe is one of the worst, if infrequent, the striking of check rails. These stresses and the resultants of them are most severe at the corners of the crank-pins and at the radii where the webs or throws join the rounded portions of the axle. These are the points at which flaws usually occur.

For about twenty years we have endeavoured to get the knowledge we have obtained into an ordered state, from observation and discussion with the metallurgists attached to the various manufacturing firms. Certain points are obvious, such as the necessity of a good micro-structure, and whilst the details in connection with exactly what micro-structure is the best are somewhat uncertain and open to debate, we can with confidence say that the steel "shall be as free as possible from non-metallic enclosures, and that the micro-structure should show uniformly distributed pearlite in a sorbitic or very finely granular or lamellar condition and be free from any nodular or balled-up cementite. It must also be free from any signs of segregation and from any coarse or overheated structure." (Extract from Midland Railway specification for crank-axle forgings.) The dimensions I have given of the size of the block of metal from which the axle is made show that it cannot have received much work, and therefore any non-metallic enclosures present will be only slightly drawn out, and will not occur as threads as they do in bars of small diameter and even in steel tyres. One of the first observations we deduced was that the life of the crank in miles had a direct relation to the ductility of the test-bar taken across the section of the throw and near the centre of the original ingot. This is the point at which non-metallic enclosures are most likely to be found, as well as that at which the greatest stress occurs. The inference is obvious that a flaw is likely to develop at some sharp corner of such an enclosure. In a section of steel such as that which must be used non-metallic enclosures are very likely to occur, and so steps had to be taken to ascertain what the best practical remedy was. With decreased carbon content greater ductility was likely to follow, and this has been shown to be the case. In a word, it is toughness rather than strength which is required, and the studied consideration of these points has led to an increased life in miles of the crank axles of the 3,000 locomotives owned by the company, in spite of the fact that they have been constantly growing in size, in pressure on the pistons, and in the work expected from them. This is shown in the annexed curve which represents the mileage of crank axles scrapped in the last twelve years. It will be appreciated that the above result, which is unquestionably the result of "ordered knowledge of natural phenomena and the relation between them," is only one example, if perhaps the most marked one, in our experience. A somewhat similar one could, however, be written on locomotive tyres and other matters if space and time permitted.

This example finishes my general remarks, and I cannot do so without expressing the indebtedness I feel to the various members of the scientific staff of our great firms for all the assistance and help they have ever so readily given us in the case I have just quoted.

One would like to press home strongly on engineers generally a point made by Dr. Maw in his Presidential Address to the Institution of Civil Engineers in November last. He pointed out the large amount of scientific knowledge—much of which was accumulated during the war—which is available at the present day. Here is the knowledge if we will but apply it to the service of man. This is our function as engineers. In times past we have had to wait for this knowledge, and as I trust I have shown, as it slowly became available it has been used in our service and in that of the world. One great need is for men with the education, the capacity, and the imagination necessary to use the scientific knowledge for the advancement of our profession. I use these three requisites advisedly, for each one of them is necessary to take full advantage of the opportunities which now exist. The trouble is that whereas we can supply education, can increase the capacity of the individual, it is difficult to instil or cultivate that imagination which allows one to see the way in which the knowledge available can be applied in a practical way.

I think I have shown adequately the debt which transport, as well as other branches of our profession, owes to the study of "ordered knowledge." That in the future this will be even more marked than at present, one can say without fear of contradiction. Not only so, but there must be more and more interdependence between science and engineering. More and more as we advance—as we are doing so rapidly—in the knowledge of natural phenomena will the necessity of the practical application of this knowledge on a large scale become necessary to confirm it and to bring out fresh features. One trusts that our Association, which has done so much in this direction in the past, may continue increasingly useful in the branch of its work which brings together those whose work is purely scientific with those who are applying that knowledge to the direct service of man. Although the old idea of antagonism between the two has disappeared, we cannot but feel that in spite of the advance of recent years the extent to which the engineer depends on the scientist for knowledge, and the scientist depends upon the engineer for the practical application of the knowledge he has gathered, is not realised as fully as it should be by either. The terms scientific and practical should be synonymous.

One would like to feel that the meeting of our

* Proceedings, Inst. of Civil Engineers, vol. xciii, 1888.

* Journal, Iron and Steel Institute, page 222, Part II, 1889, ENGINEERING, vol. xlviii, pages 471, 502.

† Journal, Institution of Locomotive Engineers, vol. xii, 1921.

Association was more generally used as the occasion on which the scientist and the engineer would meet in larger numbers. I know that the scientist is often an engineer, and that the engineer has nowadays to be a scientist with a broad outlook, but the personal contact of the two which this meeting offers gives an opportunity the results of which would be incalculable if that opportunity were fully grasped. If one might use an illustration which I trust will not offend my scientific friends, scientific knowledge is a tool of infinite possibilities, and this knowledge is possessed by so many who attend here. The practical engineer is always attracted by tools. There is no better method of ascertaining what new and improved tools of this type are available than by coming here. Beyond all this, personal acquaintance is of greater and more permanent value from every point of view than a paper acquaintance.

I would like, in closing, to make an appeal for a freer disclosure of results obtained in practical working. This can only be done by taking care in noting the behaviour of apparatus, material, &c., in use, and placing the results freely at the disposal of the man of science and of the manufacturers. At the present day there is no lack of those who are trained observers, and I believe one of the troubles often encountered by manufacturers who are applying some new method is the difficulty of getting dependable figures of performance. With transport companies this should not be a difficult matter, for one great advantage they have now is that there is no trade necessity to hide their results in any way. It is one small way in which they can repay the great debt they owe to science, which has allowed them to complete so satisfactorily their task. As Kipling has so rightly and concisely stated :—

> "It is their care that the wheels run truly, it is their care to embark and entrain,
> Tally, transport, and deliver duly the Sons of Mary by land and main."

ROAD TRANSPORT.*

By A. E. BERRIMAN.

IN the allotted space of 15 minutes it is, of course, only possible for me to review a few of the items in the published synopsis, but very cheerfully, I leave to others the pleasure of filling the lacunæ by discussion.

In order to facilitate a rapid review of the field, I have divided the subject into four parts :—

(1) Freight transport by road and by rail.

(2) Types of commercial vehicles and their suitability for different purposes.

(3) Passenger vehicles, private and public.

(4) Roads improvement and traffic control.

Freight Transport.—It is impossible to do justice to the engineering side of this subject as represented by the various types of mechanical vehicles used in road transport unless they are seen against a background representing road transport in its relation to inland transport as a whole. These broad political and commercial aspects of the subject, which must at all times remain the root of its importance, are just now of especial interest because railway freight rates and motor vehicle legislation are both in the melting pot.

Half the freight revenue of the railways is derived from the higher grade loads that account for only one-fifth of the total weight. If, therefore, the other 80 per cent. is also profitable, it is plausible to infer that these higher-class rates are excessive, or, alternatively, it must be assumed that the railways would be genuinely embarrassed by a serious diversion of this class of traffic.

The causes that have contributed to the diversion of freight from the rail to the road are, *au fond*, economic, but they are not limited to a mere comparison of railway charges with road haulage costs. In commerce, the convenience of door to door transport often provides financial advantages that overweigh higher freight rates. Loading and unloading costs are reduced, packing expenses are often materially less, while damage through rough handling and loss through pilfering may be practically eliminated.

Taking the same range of daily lengths of journey by road and by rail, it would appear that a 5-ton lorry hired on a rational scale of charges can compete with class 1 railway rates, a 3-tonner with class 2, and a 2-tonner with classes 3 and 4. Class 5 rates are higher than any rational haulier's charges except those appropriate to a service of 1-ton vehicles.

These comparisons are on the assumption of a full load both ways and for 250 days in the year, whereas the railway rates are a common carrier's charges. If the road vehicle is privately operated in connection with the routine business of a company, or is the property of a haulier with well-established contracts, its load factor, in one direction at any rate, may reasonably be expected to be high; and, according to the evidence of existing services, its average can attain to an economic value.

The case of the road haulier at large is somewhat different. He is much more likely to be troubled by a poor load factor, which is the common lot of freight transport vehicles that depend on chance trade. There are, for example, about 530,000 merchandise wagons on the English railways, and although statistically the average load per wagon in use is 50 per cent., the ratio of the average daily traffic to their combined capacity is only in the order of 6 per cent.

Railways are not likely seriously to be embarrassed by the loss of chance freight trade, but they may expect to lose an appreciable amount of the more important regular business unless they can improve their freight mobility in such a way as to effect economy in time and in money. Could not more use be made of the container principle, the container being a unit that can be carted with equal convenience by road and by rail? Improved crane facilities would be necessary at selected terminals, so situated as to make most use of the full delivery radius of motor transport.

The railway companies' proposal to operate their own road vehicles for through traffic offers no solution to the technical problem, and was regrettable evidence of lack of faith in the ability of their engineers to secure to the community, in the face of this new competition, commercial benefits that are commensurate with the technical advantages of the railway principle. This principle is necessary to the country and the railway companies are its custodians.

One of its chief advantages is a tractive effort of only about 5 lb. per ton at moderate speeds compared with about 60 lb. per ton on average roads. From this point of view, it is, technically, a sheer waste of energy to transport by road between distant points that are rail connected.

Types of Commercial Vehicles.—The majority of vehicles used in road transport are petrol driven, this system being distinguished by lightness in constructional weight and by the general suitability of the fuel. For the heavier freight traffic on roads, steam has a considerable vogue in England where our much criticised climate provides a copious supply of water in the streams from which these vehicles replenish their supplies every 25 or 30 miles. One of the chief virtues of the steam vehicle is popularly supposed to be the cheapness of its fuel, but its practical success is probably better founded on other grounds. Theoretically, coal yields about eight times more heat than petrol for the same money, and, allowing for inherent differences in the two systems, from two to three times as much road wheel energy for equal cost, but, in practice, if the conditions are unsuitable or there is much carelessness, the relative fuel economy of the steamer is not realised in this degree.

One of the lessons that makers of heavy petrol vehicles should learn from the performance of the steamer is the need for providing means for starting the engine from the driver's seat in order to save standing losses with an expensive fuel. If an electric vehicle is a commercial possibility under suitable conditions, surely there ought not to be an insuperable prejudice against electric starters on commercial petrol vehicles.

In the direction of combining a cheaper fuel than petrol with the high efficiency of internal combustion, there has been considerable experimental work, but as yet no established commercial success. Vehicles have been run experimentally with "semi-Diesel" engines, so called. If the use of a heavy distillate, such as kerosene or gas oil, is rendered really practicable under the conditions of road transport, its convenience will make it a serious competitor with coal, and its cheapness will put it ahead of petrol for use in commercial goods vehicles. Kerosene at 10*d.* per gallon should yield in an internal combustion engine practically as much road wheel energy for the same cost as high grade coal at 50*s.* per ton used in a steamer.

There are two classes of heavy transport vehicles that derive their distinction not from a difference of engine, but from their peculiar means of supporting the load. They are the six-wheeler and the track machine. In the former, the real object of using three axles instead of two is not to reduce axle weight, but to enable heavier or bulkier loads to be carried on a single platform without exceeding the permissible limits of size and weight. In the track machine, the increase in load-carrying capacity is accompanied by an immense reduction in equivalent axle weight, but the main object of this design hitherto has been to enable heavy loads to be negotiated successfully over soft unmade ground, or even sand and snow; essentially, they have been roadless vehicles, and, as everyone knows, they scored a phenomenal military success as "tanks." The commercial future for this type of machine very largely depends upon the technical enterprise with which its limitations are overcome in directions that have precluded it from participating in the normal traffic on hard roads. Such a machine, properly suspended and steered, would cause very little damage to the roads; in principle it is a mobile railway.

Passenger Vehicles, Private and Public.—Time is too short for more than a passing reference to the private car and motor-cycle, but there would be little need to say anything of an explanatory character about a branch of technology that is nowadays commonplace knowledge in every family circle. At the present time, there are about 350,000 private cars and a somewhat larger number of motor-cycles. The combined figure and that of persons with incomes of upwards of 400*l.* per annum is probably not very dissimilar. In comparing these figures, the social significance of the motor-cycle must not be belittled, for apart altogether from the young feminist movement in favour of pillion riding, it is a matter of common observation that a vast number of motor-cycles have side-car attachments and carry, upon occasion, as many passengers as the average car. The motor-cycle and side-car may not be an aesthetic combination, but, from the engineering point of view, it is a fine achievement in economy of weight and constructional cost, and it is remarkable for the fact that the motor-cycle in this state has been saved from the sacrifice of original merit that so often results from attempts to enlarge the sphere and purpose of machines by grafting additional ideas.

Externally, the constructional features of private car chassis have not changed much for several years, but there is a tendency now to fit the faster cars with brakes on all four wheels, and, in some cases, to provide auxiliary force for their application. The greatest steady progress has been in the development of the high-speed engines that have done so much to popularise the smaller car, and it must be admitted that this side of automobile engine development owes much to the influence of racing, which has encouraged high engine revolutions as the direct means of securing high road speed. Modern racing car engines are being built to run at 6,000 r.p.m., which means a piston speed in the order of 4,000 ft. per minute, and to develop over seven times their R.A.C. rating. Engines on the larger private cars as used by the public probably develop about twice their rating. A considerable advance has also been made in high-speed work with sleeve-valve engines, and it has drawn attention to their possession of qualities over and above the enduring silence on which they have chiefly maintained their popularity and commercial reputation. Two important points of advantage possessed by this system are an approximately spherical combustion chamber and the absence of springs in the valve mechanism.

No reference to progress in connection with private cars would be complete without an acknowledgment of the great improvement that has recently taken place in the durability of pneumatic tyres through the adoption of the cord principle of construction. The average life is probably at least double what it was a few years ago. This result encourages the belief that it will only be a question of time before the pneumatic principle holds sway in a wider field than it controls at present. We have only to consider what private cars would be like with solid tyres in order to realise how much the heavier classes of vehicles would stand to gain if the general adoption of pneumatic tyres were justified. It is to be hoped, too, that the pneumatic tyre itself may be improved in other directions besides longevity as, for example, by an increase in shock-absorbing capacity.

In the design of motor 'buses for use in London and other congested cities, the problem of weight reduction is paramount because of the need of more seating capacity without increasing either the size or the weight of the individual vehicle. The latest London 'buses seat 54 passengers and are designed to the maximum permissible limits of size and weight. While it would be rash to assume even with these limits that they have reached finality in their seating capacity, nevertheless, it certainly looks as if some radical weight-saving change in design will be necessary for further progress.

The place of the motor 'bus as an essential road passenger vehicle is too obviously assured to need debate, nor is any useful purpose to be served here by attempting an economic comparison of it with the tram. The road is the natural home of the completely mobile vehicle and whether the extension of rail traffic thereon is, or is not, justified in particular instances, the fact remains that fixed rail transport is not road transport, and the more thoroughly does any form of rail transport justify itself on merit, the more completely does it call for treatment as a system apart.

There have been certain cases of late in which tramway companies with worn-out tracks have avoided the expense of relaying by adopting a compromise called the "trolley 'bus," which runs on the road surface while drawing its power from a pair of overhead cables. Technically, the characteristics of the electric motor as applied to road traction differ significantly from those of the petrol engine combined with a gear-box, and for a comparable weight of equipment and tractive effort on hills, the ultimate speed on the level will be less with a trolley 'bus than with a petrol vehicle, although it does not follow that it need be inadequate for practical purposes over a chosen route on which the petrol 'bus can operate satisfactorily with a three-speed gear-box. For general road traction, as for general rail traction, the electric vehicle of reasonable weight needs a mechanical two-speed gear in order to do itself justice.

Roads Improvement and Traffic Control.—When all has been said with regard to the vehicle, its possibilities and its technicalities, the fact remains that the achievement of its purpose depends absolutely on the road. Roads improvement is, therefore, a national problem and was well described by Adam Smith in his "Wealth of Nations" as the "greatest of all improvements."

The Roads Department of the Ministry of Transport has classified 22,000 miles of roads towards the maintenance of which it contributes 50 per cent., and 14,000 miles that receive 25 per cent. The mileage of other roads in England, Scotland and Wales amounts to about 177,000, and the total cost of road maintenance is in the order of 40,000,000*l* per annum.

The contribution of the Ministry of Transport is derived from the proceeds of motor taxation, the gross receipts from which exceeded 10,000,000*l.* last year. What part of the total necessary expenditure on roads it is equitable to impose upon the owners of automobile vehicles is a vexed question that deserves unbiassed and statesman-like consideration. The crucial point of equity in this matter is a question of amount. Roads are a national heritage in the use of which all members of the community participate, and none can logically claim exemption from the moral obligation to contribute something towards their proper maintenance and reasonable improvement.

The most obvious and most important advance that has been made in roads has been in the general adoption of waterproof principles of construction and repair, but a considerable amount of work has also been done in the widening of roads and in the minimising of dangerous places, all of which tends to facilitate the proper functioning and automatic control of traffic.

If we can learn anything from the present conditions in America, where new cars are being produced at the rate of 5,000 miles per annum, there is surely no subject more important than the automatic control of traffic. With all deference to the authorities who have been putting up the warning signs, I submit that they have proceeded on wrong lines, and I argue that ultimately it will be necessary to future safety definitely to

* A paper read before Section G of the British Association, at Liverpool, September 14, 1923: Abridged.

THE FUTURE OF TRANSPORT BY RAIL.

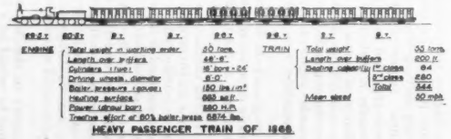


FIG. 1.

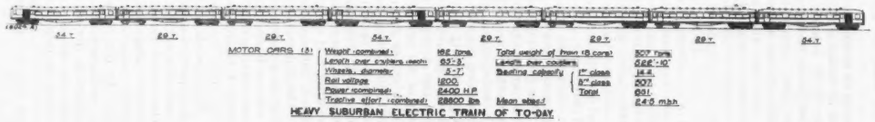


FIG. 3.

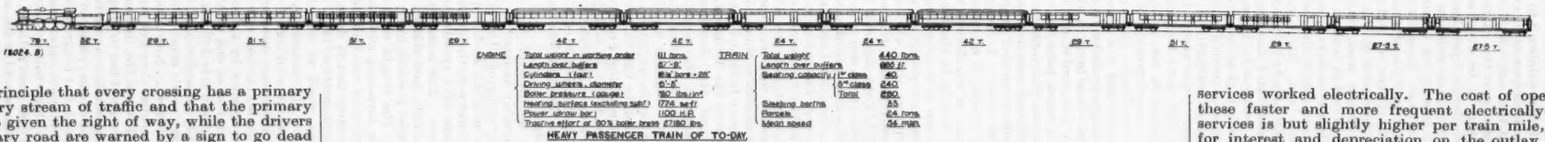


FIG. 2.

work on the principle that every crossing has a primary and a secondary stream of traffic and that the primary traffic must be given the right of way, while the drivers on the secondary road are warned by a sign to go dead slow. The primary traffic cannot afford to slow down at every crossing and does not, in fact, do so. Warning signs in general, therefore, have come to be regarded with far less respect than they deserve. This principle of automatic traffic control is applicable, to a considerable extent, to towns as well as in the country, and the cost of providing the necessary signs would not be more than it is worth in the long run to secure the benefits that would accrue from the system. One thing only would be needed to ensure its success, and that is the support of the courts in litigation arising from accidents.

THE FUTURE OF TRANSPORTATION BY RAIL.*

By Colonel E. O'BRIEN, D.S.O., M.Inst.C.E., M.I.E.E.

A BRIEF survey of the probabilities of the future of rail transport must be incomplete without some reference to the past. The advent of steam hauled transportation by rail in 1831 was destined to affect profoundly the future of the human race: the intermingling of nations hitherto effected mainly by mass movements of a warlike character changed in a few years to a gradual filtration of populations, the change being due almost entirely to the shortening of time distances by cheap and efficient rail transport. This new power of faster locomotion also had a far-reaching effect on the economic life and habits of the world population and has resulted in radical alterations in methods of housing and in basic food consumptions; building materials, formerly dear and inaccessible, have become accessible and cheap, and exotic foods have become common articles of diet. To rail transport, too, may be attributed in the main the vast increase in population of all civilised countries that has taken place in the last hundred years.

What has been the engineer's contribution to this revolutionary world change, and what has he to offer for the future? In the last sixty years the average speed of main line passenger trains in this country has increased from 30 m.p.h. to 50 m.p.h., the weight of train behind the drawbar from 100 tons to 500 tons, the weight of rail from 60 lbs. to 100 lbs. per yard, the weight of locomotive from 50 tons to 148 tons (engine and tender), the heating surface and grate area of boiler from 880 sq. ft. and 15 sq. ft. to 3,400 sq. ft. and 41 sq. ft., and the working pressure from 120 lbs. to 225 lbs. per square inch. Figs. 1 to 3 show in comparative form steam trains of 1868 and 1923 and the modern 8-coach multiple unit electric train. These figures represent a remarkable increase, but the increase was of extremely slow growth, and in effect the steam locomotive is in principle unchanged since its invention was perfected in 1829. The improvement that has taken place has been wholly in quality of material and method of manufacture; even superheating was applied by Trevithick to a locomotive boiler in 1832, while McConnel in 1854 actually demonstrated its great economy in traffic.

Comfort of travel has also greatly increased; the comparatively well electrically or incandescent gas-lit comfortable coaches of 1923, weighing 30 tons, bear no comparison with the dismal oil-lit boxes of 1863, which weighed only 9 tons, while dining cars and sleepers were unknown at that date. There appears, however, to be still considerable room for improvement in the direction of the further reduction of noise and vibration—the two principal sources of fatigue in railway travelling. The public has come to regard these as inseparable from railway travel, but there is no sound engineering reason why both noise and vibration should not be much further reduced. Dust is also an annoyance to travellers, but this has been greatly reduced by the use of stone ballast, and in time the competition of aerial travel will probably drive the railway companies to its complete elimination.

While speeds and comfort have increased, the cost of transport has not declined in like degree: the cost of a third return ticket from Manchester to London was *1l.* 11*s.* 4*d.* sixty years ago, so that the fare of *2l.* 6*s.* 4*d.* of to-day does not show any appreciable reduction allowing for the index number, while goods rates have actually risen above the level of sixty years ago; in effect the change has been in the giving of a much better and more comfortable service to the public at the same cost, with vastly better conditions and higher wages for the railway employees.

Probably the greatest step forward effected was the introduction of the vacuum and Westinghouse brakes which enormously increased both the safety and speed of travel, an increase which, however, would not have been possible had it not been accompanied by the development of the block system of signalling and track circuiting.

The most radical innovation in rail transport, however, had been the application of electric power to transportation, the extensive use of which commenced about 20 years ago. The principal developments of its use have been for suburban services and main lines with heavy gradients. There is still a large field for the further extensive application of electricity to suburban traction. A double track suburban railway if electrified can provide a service of 30 trains of eight cars each per hour, equivalent to 15,000 passengers per hour or 30,000 passengers in the two rush hours inwards or outwards: this means that such a route can serve a suburban population of about 200,000, and that a reduction in time of transit from suburb to business centre of about 25 per cent. can be effected economically. At present, but four of the large towns in this country have a portion of the suburban services worked electrically. The cost of operation of these faster and more frequent electrically-operated services is but slightly higher per train mile, allowing for interest and depreciation on the outlay involved, than that of the slower and less frequent steam services. The profit per passenger carried, therefore, remains constant, but as in nearly every case the carrying capacity of the line electrified has been doubled and the increased capacity has been absorbed by the increase in passenger traffic, it is clear that such electrifications have been profitable to both railway companies and public alike. A very slight lowering of rates of interest and in the price of the material required for such electrifications is likely to produce a very considerable development in future. There are no engineering difficulties to be overcome while the only technical point at issue is the most suitable voltage for the third rail; natural development has standardised 600-650 volts in the London area, but if the recommendations of the departmental committee of the Ministry of Transport are followed 1,500 volts will be used in future round other cities.

The 1,500-volt under-contact third rail as now developed is likely to prove perfectly safe and satisfactory, and will permit of the future use of either 3,000 volts overhead collection or 1,500 volt third rail collection for main line work where required in future.

The electrification of main lines has made very considerable headway in the United States, and is rapidly developing in Switzerland, Norway, New Zealand and Japan. It may be noted that each of the main line electrifications in the U.S.A. has been forced on the railway company concerned either by city ordinances against smoke, tunnel conditions, by the existence of long and severe gradients, or by dear coal in the presence of cheap water power. It is of interest to consider whether there is any future for main line electrification in this country where these conditions are not determinant factors. The average thermal efficiency of the steam locomotives in Great Britain probably is not in excess of 2 per cent.; tests of modern steam locomotives in first class condition with the best coal under conditions of maximum efficiency do not reveal an average thermal efficiency of more than 4 per cent. on the basis of the actual coal burned between terminals, and exclusive of coal used for lighting up, shunting, &c. Fig. 4 shows the results of two tests, the second of which with a 500-ton train was intended to approximate to the conditions which would exist with electric traction. The diagram shows clearly how the greater horse-power of an electric locomotive will enable a much higher speed on upgradients to be maintained with heavier trains. The thermal efficiencies of large modern power stations working at 40 per cent. to 50 per cent. load factor may be expected in the near future to be as high as 20 per cent.; allowing for 84 per cent. for the efficiency of transmission and conversion, 90 per cent. for the rail and 75 per cent. for the electric and mechanical efficiency of the locomotive, equivalent to 56·6 per cent. overall, the total thermal efficiency from coal pile to drawbar for the electric locomotive is about 11 per cent. A general electrification of an average section of busy main line might therefore be expected to diminish the coal consumption by at least two-thirds. This figure is confirmed by independent

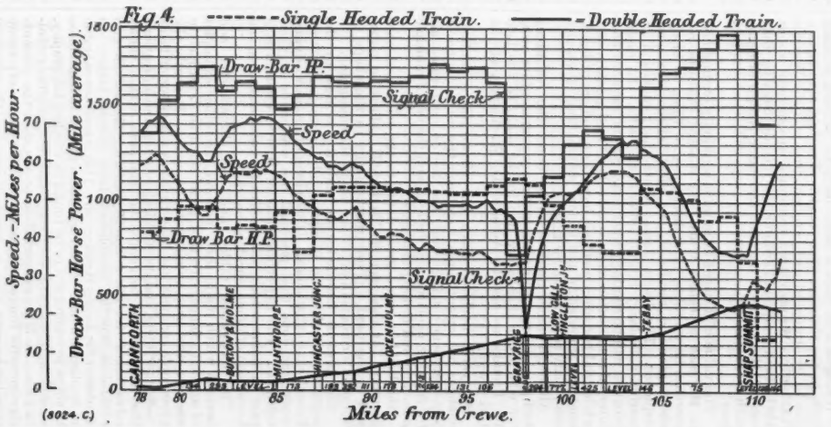


Fig.4. ------Single Headed Train. ——Double Headed Train.
Draw-Bar H.P.
Signal Check
Speed
Speed
Draw Bar H.P.
Signal Check
Speed.-Miles per Hour.
Draw-Bar Horse Power. (Mile average).
1800
1500
1000
500
0
70
60
50
40
30
20
10
0
CARNFORTH
PRESTON
WIGAN
WINDLE
WIGAN
KIRKHAM
WIGAN
WIGAN
WIGAN

calculations made by Sir V. Raven in connection with the N.E. section of the London and North Eastern Railway, as quoted by him in the *Railway Gazette* of June 22, 1923. Calculations by the author in connection with sections of the London, Midland and Scottish Railway indicate a similar result. The cost of coal for generating current, however, is roughly only one-third of the total cost of current delivered to the locomotive, so that as a matter of finance, as coal prices now stand, coal on the tender and equivalent current at the collecting shoe of the locomotive will be about equal in price after covering all capital charges on the electrical equipment. Economies apart from advantages will, however, be found in the cost of the repairs of the electric locomotive which will be one-third to one-quarter of those of a steam locomotive per mile run, and in the employment of a single driver per locomotive instead of a driver and fireman. Advantages will also accrue from electrification on which it is difficult to set a money value; local train services will be worked with multiple unit stock, thus greatly reducing locomotive movements at terminals; electric locomotives will not require to turn, which further eliminates shunting. From the traffic point of view, important advantages will accrue due to the characteristic of the electric locomotive, enabling higher speeds to be maintained on rising gradients, from the greater uniformity of speed of passenger and goods trains which will result from the above; from the greater security obtainable on falling gradients by fitting a rheostatic brake on the locomotive, the higher average speed obtainable with goods trains, the greater cleanliness in stations, the availability of an abundant electric supply along the railway for lighting, track circuiting, signal operation, &c. There is no doubt that the electrification of any main line containing gradients of 1 in 300 or greater and averaging over two trains per hour in each direction would at least involve no loss of any kind to the company undertaking it, while the indirect advantages to both the railway company concerned and the electrical industry of the country would be very large. Where the traffic is denser and the grades heavier than mentioned above a handsome return on the capital expenditure might be expected.

From the Ministry of Transport statistics it will be seen that in 1922 the average cost of operation per train mile for all classes of traffic in Great Britain was 10*s.* 10*d.*, of which the locomotive expenditure on operation and repairs amounted to 3*s.* 7*d.* On the assumption that a saving of one-third of the cost of locomotive operation would be effected by electrification the total saving in the cost of operation would be 11 per cent. Owing, however, to the enormous capital expenditure which would be involved in the electrification of the many branch lines with sparse traffic the economy effected would not be anything like 11 per cent. If a general electrification became possible due to some invention reducing the capital cost involved, and particularly if the cost of construction of the electric locomotive could be reduced, no doubt the result would re-act favourably on the public, but for the time being only special sections will be worth electrifying from the railway companies' point of view. If such electrifications can be carried out without loss or even at a small profit the railway companies would be indirectly, as well as directly, benefited, because the evidence of the success of British electrifications by British firms could hardly fail to stimulate electrification in other countries, bringing at the same time work to this country, which would increase the export trade that is vital to population, traders and railway companies alike.

It would appear, therefore, that broadly the physical limitations of the existing railways both in this and other countries forbid any appreciable further acceleration of services or substantial reduction in cost of transit except in a general raising of the standards to the highest at present existent and in certain special directions.

SEA TRANSPORT.*

Transport and Its Indebtedness to Science; Sea Transport.

By A. T. WALL, O.B.E., A.R.C.Sc., M.I.N.A.

BEFORE discussing the future of transport by sea its history should be examined. Shipbuilding is probably one of the oldest industries, and the sea has always held a strong fascination for man, which seems likely to endure.

Ship construction has evolved slowly and painfully by a process of "trial and error." We have moved along very slowly from the early days of the "dug-out" canoe to our present-day engine-propelled monster liners. For centuries ship construction showed little real advance. Certain it is that science has only played an important part in naval architecture within recent times, and it is equally certain that the last century has seen more advances made than any other half-dozen. The comparatively rapid advance made in the last century or so is mainly due directly to the application of science. None the less the "trial and error" method still maintains itself, and is likely to do so for some time yet, indicating the enormous scope still available for the application of scientific methods.

Two or three generations ago the scientific side of naval architecture and marine engineering, such as it was, was catered for by mathematicians and civil engineers. To-day we have a number of men, young and old, who have been specially trained for their work; luckily the training continues.

From time immemorial timber has been the material used for ships. Then came bolder spirits, frankly considered mad at the time, who introduced iron as a material in place of wood. It would be impossible in a short paper to trace the history of all radical departures, but it may be as well to remind ourselves of the difficulties met with by the pioneers of iron vessels.

As far back as 1787 a canal boat was built of English iron. She was 70 ft. long, with shell plates five-sixteenths of an inch thick. About 1815 a small iron boat was fitted up as a pleasure boat in Liverpool. She was sunk maliciously in the Duke's Dock. The owner, named Jerons, was impressed with the practicability of iron for ship construction but he was before his time. Meantime, the use of iron was ignored by the Royal Navy, and even in 1850 an admiral declared his conviction that the ships of the Navy would never be built of iron and driven by steam. In 1861 Parliament voted nearly one million pounds to replenish the stock of wood in the dockyards, a sum far in excess of any previous vote for that material.

It was not until about 1821 that the first iron steamer, the Aaron Manby, put to sea, and wood continued to be chiefly used until near the middle of the nineteenth century. The Royal Navy only commenced to use iron in 1859; even then the displacement of wood was gradual.

The step from iron to mild steel was an easier one than that from wood to iron, but there has been little progress in the use of mild steel since its introduction. An increase in ultimate breaking strength of at least 20 per cent. was considered to be the great advantage of mild steel over wrought iron. The saving in weight of structure in consequence was from 10 to 15 per cent. Steel is also more ductile and reliable.

Wrought iron plates were used to protect wooden hulls in the Crimean War (1854). The first ship of any size to be armoured with wrought iron was the Warrior (1859–61). Wrought iron continued in use until about 1881; then compound armour was introduced, after that came "Harveyised" armour and later Krupp armour, with a resistance three times as great as that of wrought iron.

The value of a scientific mind is strikingly exemplified in the case of James Watt. By making scientific researches he was able, in a short space of time, to bring about practical results of the most far-reaching consequence. Thanks to James Watt the foundation of marine machinery is undoubtedly scientific. Its rapid progress can be similarly qualified. Steam turbines and internal combustion engines have developed quickly, and while trial and error methods have been and are utilised, scientific knowledge and logical marshalling of results are chiefly responsible for this.

Although much remains to be done, the resistance and propulsion of ships has become a science of its own, for which our thanks are due in the main to the late W. Froude, as also to Admiral D. W. Taylor, of the U.S. Navy.

Shipyard machines have not shown many radical changes but recent times have seen the introduction of oxy-acetylene cutting plant, the use of compressed air for riveting, caulking and drilling, and the use of multiple punching and drilling machines.

Shipbuilders owe a great debt to the science of pure geometry for their art of "laying-off" ships on paper and in the yard. Pure mathematics in the shape of Simpson's rules is in everyday use in ship designing.

The present knowledge of stability is due to the pioneer work done by Bouguer and, in the main, other French mathematicians. It was long after their original work was done that practical use was made of their methods. The regrettable loss of H.M.S. Captain is a case in point where prior scientific calculations would have been of immeasurable service.

The navigation tables, and the chronometer and sextant which made them possible, are other examples of applied science. To that great scientist Lord Kelvin we owe the present magnetic compass. Recently the gyroscopic compass has been fitted in a number of large passenger liners, and the Admiralty have given indications that they intend to adopt this compass, which shows advantages over the magnetic pattern. Gyroscopic gun control is now an established fact, thanks largely to Professor Sir James Henderson. This is another example of applied science. Other instances of the indebtedness of ships to science are to be found in wireless telegraphy, electric appliances on shipboard and refrigerating installations. It is no exaggeration to say that the present-day monster liners and battle cruisers were only made possible by men with a thorough grasp of the scientific principles of naval architecture.

There are many problems for the future. It is true to say that naval architecture and marine engineering are sciences, but, as yet, inexact sciences. Science must and undoubtedly will gradually displace art. It would be possible to make a long list of items requiring solution, in all of which more exact knowledge would be of immediate value. For example, our information on the behaviour of ships at sea is meagre; this includes rolling, pitching and stability. Strength calculations have gradually become more useful to the designer but at present they are relative rather than absolute. Much research work in experimental tanks and at sea is required to improve our knowledge of resistance and propulsion. As the fouling of ships' bottoms affects the running economy so adversely, its prevention is an important matter. Labour processes should be simplified. Good work has already been done on the subject of the corrosion of metals, which term is often used to include corrosion proper, chemical exfoliation, erosion and scale formation. Much, however, remains to be done.

The need for research work is obvious, for whilst, fortunately, lucky discoveries will still occur, it is apparent that most difficulties will only be overcome by systematic scientific investigation.

As in all engineering work, our present lack of knowledge forces designers to use what the late Professor Perry called a "factor of ignorance"; the more this factor is reduced the better the progress.

Some changes are taking place now. The internal combustion engine is rapidly gaining ground, but its power is still limited. The internal combustion engine as we know it at present, although an advance in many ways, is in reality a retrograde step in that it has taken us back to the reciprocating engine, and as such, is admittedly more difficult to make perfect as compared with the steam reciprocating engine. The gas turbine would obviate this retrogression, and although many minds are working on this at the present time, there are many difficulties to be overcome, not the least of which is the metallurgical problem.

Electrical transmission is beginning to establish itself. Double gearing for steam turbines is under a cloud at the moment. Superheated steam finds some favour and its economy is affirmed. Higher pressure for steam boilers is spoken of, and the future must eventually see the displacement of the smoke-tube by the water-tube boiler. Some work has been done on the use of powdered fuel in boilers. Solid fuel continues in favour for boilers as against liquid except in special vessels.

Mention was made earlier of the advantage of mild steel over iron. Some use has been made of high tensile steel, particularly in warships, and in the Cunard vessels, Mauretania and Lusitania. Its use has been discontinued principally because its elastic limit was not sufficiently high although its ultimate strength was great. A change is coming whereby elastic limit will be the criterion of strength of a metal and not its ultimate strength. Other things being equal a metal with a high elastic limit is to be preferred. There is already on the market and in use a high elastic-limit mild steel. It is the development of a well-known metallurgist, Mr. F. G. Martin, of Liverpool. The determination of the elastic limit of a metal is now commercially possible. The changes probable from this innovation are comparable with those brought about by the substitution of mild steel for iron, and should have far-reaching consequences.

The riveted joint has remained practically unaltered since it was first introduced. At best it is crude and its most efficient practical form reduces the strength of the materials connected together to about 80 per cent. of their full value. It seems doubtful whether the riveted joint is capable of much improvement, but during the past ten years or so, electric welding has made rapid strides, thanks largely to the labours of Mr. A. P. Strohmenger in the use of flux-covered electrodes, as exemplified in the Quasi-arc process of electric welding. It seems safe to prophesy that electrically welded connections will eventually replace riveted joints. Careful tests carried out by Lloyd's Register of Shipping have demonstrated their efficiency, and in addition to some barges, an all-welded self-propelled coasting vessel has been built by Messrs. Cammell Laird and Co., Limited, of Birkenhead, a firm ever famous in pioneer work since its inception early in the nineteenth century. This vessel, originally the Fullagar, and now the Caria, has proved eminently satisfactory on service with two sets of owners.

One recalls in this connection the vessel Archimedes, built about 1836 and fitted with a screw propeller. She raced with the Widgeon, a fast paddle steamer for that time, and the Archimedes decisively illustrated the advantage of the screw over the paddle-wheel. None the less the Archimedes lay unemployed in dock and the man, Mr. Thomas Smith, to whom the world was indebted for the introduction of the screw propeller, lost all the capital he had embarked. How long it will be before the lesson of the Fullagar is learnt only the future can show, and this is said keeping in mind economic considerations. Mention should be made of the Michell thrust block, which is revolutionary. It has also made possible the crankless engine for which a great future is predicted.

The solution of the problem of corrosion will be considerably assisted by a new process, called Metallisation, for spraying all metals with copper, zinc or aluminium *in situ* or in the workshop.

Machinery with larger powers, higher temperatures, pressures and speeds has brought its own particular problems. The metallurgist is busy solving these, and he has only just started his labours. Improved metals will make possible many things now regarded as impossible. The weight of a ship is clearly a matter of the first importance, and there is plenty of scope for the lightening of the hull, machinery and fittings of ships. Everything that is done to reduce weight and decrease fuel consumption is a step towards augmenting the average speed of vessels and increasing the general efficiency of transport by sea.

A very hopeful sign for future progress is to be found in the increasing number of scientific experiments, on a large scale, carried out by shipbuilders and engineers, and sometimes by shipowners; although not so much by the latter as one would wish. In the routine rush of the shipyard it is difficult to spare time for investigations, generally complicated, based on scientific principles. Research work must generally be separated from commercial work. New processes are often looked at askance because they involve risk and trouble; the existing method offers the line of least resistance and this fact is often a great bar to progress. Science frequently shows that an established practice is wrong or can be improved. Experience may, and often does, precede the scientific treatment, but progress is much more rapid when science is used to guide experience.

That ships will continue to improve in the future as in the past goes without saying, but he would be a bold man who would state what form these improvements will take. When Henry Bell built the Comet her engines produced about 1½ h.p. for each ton of machinery weight; to-day the machinery of a modern torpedo boat destroyer produces about 70 h.p. for each ton of machinery weight, an increase of about 50 times, and an aeroplane engine gives about 1,200 h.p. for the same weight of machinery, an increase of 900 times. The sets are

* A paper read before Section G of the British Association at Liverpool, September 14, 1923.

not strictly comparable, of course, but the figures are eloquent.

The earlier marine engines consumed about 6 lb. of coal per hour for each horse-power. To-day a marine oil engine consumes about four-tenths of a pound for each horse-power, approximately one-tenth the consumption allowing for relative fuel values. To-day we have boats which skim the water at high speeds, and boats which skim the water and fly in the air. Will such craft develop into larger sized vessels for open sea work? Shall we ever see liners skimming the Atlantic? It seems safe to say that our merchandise will continue to be carried in "displacement" ships as now, for many years to come, but in ships vastly improved in construction and in propelling machinery, and possibly with reduced resistance to propulsion. Aeroplanes have made so much progress in less than twenty years as to stagger the naval architect thinking in terms of the progress of ship construction. It does seem probable that fast passenger transit in the future will be conducted in the air rather than on the sea, and in fact this is already the case with some passenger traffic to the Continent of Europe.

If new sources of energy are tapped the problem changes entirely, but it would appear that liquid fuel will be the source of energy for some time to come, and if this be so, changes of a revolutionary character do not seem likely to take place.

The importance of education in engineering, which includes naval architecture, is becoming more fully recognised. Rule of thumb methods are no longer considered sufficient. None the less the importance of experience and practice must not be underrated. There is a regrettable tendency to-day to attempt to draw a distinction between so-called theory and so-called practice. There is no sharp line of demarcation, and the very attempt to separate the two is retarding progress. Engineering is becoming more and more complicated, and the mental level of engineers must be raised in consequence. There is perhaps a tendency to stress the technical side in some courses laid down for the training of engineers; the applied side must not be overlooked, and early training in the workshops is most important in this connection. There is no doubt such a thing as pure theory, but that to be useful must become applied theory. The great value of the scientific mind lies in its power of applying logical reasoning to the results of experience, but that mind must be placed in contact with such results.

Whilst many every day engineering matters are not amenable to absolute scientific treatment, a relative treatment is possible which is extremely valuable. Science often becomes practice and the more it does so the greater the progress. It must be kept in mind that financial considerations ultimately decide the success of a conception, and commercial, practical and scientific considerations must be co-ordinated. Shipbuilding enlists the services of many others besides shipbuilders and engineers, such as chemists, metallurgists, electricians and oil technologists, so that the need for the closest co-ordination is paramount. This need is probably the most important conclusion to be drawn from a consideration of the title of this short paper. Such meetings as these of the British Association are therefore of great value.

THE EFFECTS OF OXYGEN ON COPPER.*

Investigation of the Effects of Impurities on Copper. Part I.—The Effect of Oxygen on Copper.

By D. HANSON, D.Sc., Member; C. MARBYAT, B.Sc., Member; and GRACE W. FORD, B.Sc., Member.
(From the National Physical Laboratory.)

(*Concluded from page* 352.)

TENSILE TESTS AT ORDINARY TEMPERATURES.

Sand-Castings.—Tensile tests of 1-in. diameter sand-castings were made on copper containing 0·02 per cent., 0·09 per cent., and 0·12 per cent. of oxygen, and the results are shown in Fig. 4. The ultimate stress was highest in the metal containing the lowest amount of oxygen, which possesses a strength of approximately 9½ tons per square inch, with an elongation of about 25 per cent. The other materials show a considerably lower tensile strength, accompanied by a much lower elongation, and it seems probable that the values obtained in this test depend more on the soundness of the castings than on the actual chemical composition.

Chill-Castings.—Similar tests have been made on a series of chill-castings, and the results are shown in Fig. 5, in which the average of two tests is plotted against chemical composition. Variations between the duplicate tests were not as a rule large, except in the copper containing 0·36 per cent. of oxygen, in which values from 13 tons to 16·6 tons per square inch were obtained, with 8 per cent. and 25 per cent. elongation, respectively. The tensile strength of chill-castings appears to rise gradually with the increase in the oxygen content from about 11 tons per square inch in practically pure copper to about 16 tons per square inch in copper containing 0·36 per cent. of oxygen. This increase in strength is accompanied by an appreciable decrease in the elongation.

Rolled Bar.—Similar tests on rolled bar are given in Fig. 6. They have been carried out on bars in the "as rolled" condition—that is, after hot-rolling from 1 $\frac{9}{16}$ in. diameter to $\frac{7}{8}$ in. diameter, followed by cold-rolling to $\frac{5}{8}$ in. diameter, and also on similar material after annealing for half an hour at 700 deg. C. The effect of oxygen is clearly marked in both series. In the "as rolled" material the tensile strength rises steadily with the oxygen content from 21·3 tons per square inch to 25·0 tons per square inch in the copper containing 0·36 per cent. of oxygen. At the same time the elongation falls from 20 per cent. to about 4 per cent. In the annealed samples similar results are obtained. Copper containing 0·015 per cent. of oxygen has a tensile strength of 14·45 tons per square inch, which rises to 16·6 tons per square inch in the metal containing 0·36 per cent. of oxygen, while the elongation falls from 58 per cent. to 34 per cent. for the same range of composition.

It will be observed that the effect of cold rolling on these materials is greater the higher the oxygen content, and the metal hardens more rapidly for the same amount of working as the oxygen content is increased. In the case of copper containing 0·36 per cent. of oxygen, the elongation is reduced from 34 per cent. to about 4 per cent. as the result of 49 per cent. reduction in area by cold rolling, and the figures suggest that the metal could not be worked to a much greater extent than is represented by 49 per cent. reduction without failure taking place. Copper of lower oxygen content still possesses appreciable ductility after this amount of working.

The rate of increase of tensile strength with oxygen content does not appear to be very great, and it is to be noted that the addition of 0·36 per cent. only increases the tensile strength by about 2 tons per square inch, in spite of the fact that the alteration in the structure of the metal is very great. "Copper" of this composition consists very largely of the copper oxide eutectic, and it is of interest to note that this eutectic can readily be rolled hot to give bars which possess a very considerable ductility, namely, about 34 per cent. in the "as rolled" and annealed condition.

TENSILE TESTS AT 250 DEG. C.

Tensile tests at 250 deg. C. have been made on a number of the alloys, and the results are shown in Fig. 6. The samples are appreciably weaker at this temperature than at atmospheric temperature, a difference of about 4 tons per square inch being found in the case of pure copper, and about 5 tons per square inch in the case of a high oxygen copper containing 0·36 per cent. of oxygen. The copper with this high oxygen content is only about 1 ton per square inch stronger than pure copper at this temperature, and it is therefore to be noted that the presence of oxygen does not appreciably increase the strength of the material at this slightly elevated temperature.

HARDNESS TESTS.

Brinell hardness tests were in each case made on the chill-cast 1 $\frac{9}{16}$-in. diameter chills, a complete cross-sectional slice of the ingot being taken for this purpose. In making these tests, a 10 mm. ball was applied under a load of 500 kg. for 30 seconds. The hardness results are given in Fig. 3. Attention may be drawn to the fact that the Brinell hardness number increases in value more rapidly than does the tensile strength with oxygen content.

NOTCHED-BAR IMPACT TESTS.

A standard single-notch Izod test-piece was used for these tests, the results of which are given in Fig. 3. Rolled bar was used, and was tested in the "as rolled" condition, and also after annealing for 30 minutes at 700 deg. C. The energy absorbed at fracture falls rapidly as the oxygen content increases, especially in the "as rolled" bar. This test would thus appear to be more sensitive than any other which has been used, in indicating changes, both in the amount of cold-work and in oxygen content, although in the case of annealed copper containing less than 0·1 per cent. of oxygen the variations are very slight even under this test.

Fig. 4. OXYGEN-COPPER ALLOYS. SUMMARY OF TESTS ON 1 INCH DIA. SAND-CASTINGS.

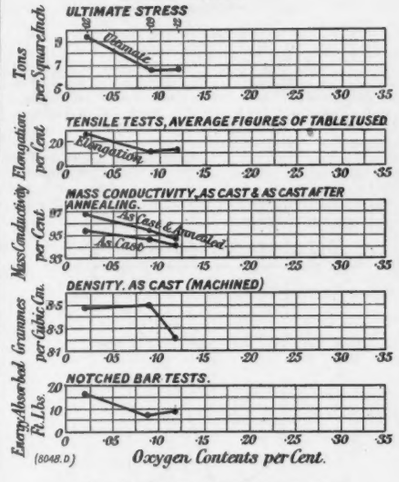


Fig. 5. OXYGEN-COPPER ALLOYS. SUMMARY OF TESTS ON 1 INCH DIA. CHILL-CASTINGS.

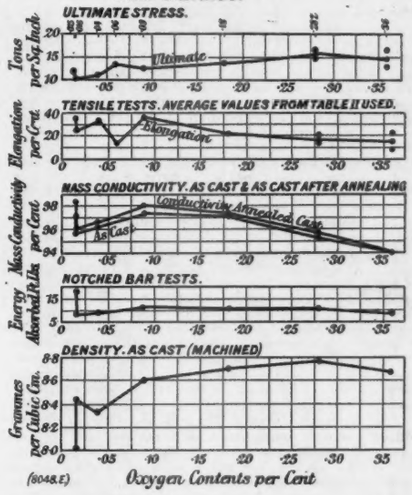
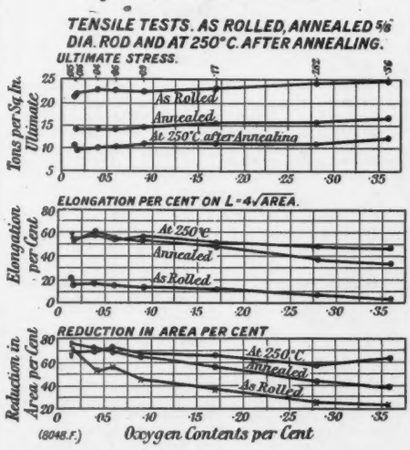


Fig. 6. OXYGEN-COPPER ALLOYS.


TENSILE TESTS. AS ROLLED, ANNEALED ⅝ DIA. ROD AND AT 250° C. AFTER ANNEALING.
ULTIMATE STRESS.
Tons per Sq. In. Ultimate
As Rolled
Annealed
At 250° C after Annealing
ELONGATION PER CENT ON L = 4√AREA.
Elongation per Cent
At 250° C
Annealed
As Rolled
REDUCTION IN AREA PER CENT.
Reduction in Area per Cent
(8048.F.)
Oxygen Contents per Cent

WÖHLER FATIGUE TESTS.

These tests were made on a series of specimens prepared from rolled bar that had been annealed at 700 deg. C. for 30 minutes. The results show a remarkably high fatigue range, having regard to the fact that under static tests copper has practically no elastic limit or yield point. It appears that copper will withstand alternating stresses which are much higher than static stresses sufficient to produce in it considerable permanent deformation.

ELECTRICAL CONDUCTIVITY.

Electrical conductivity tests have been made on sand and chill castings, both "as cast" and after annealing for 30 minutes at 700 deg. C., and on rolled bar in the "as rolled" condition, and also after similar annealing. The results are given in Figs. 3, on page 352 *ante* and 4 and 5 above.

In determining the relative conductivity given in the tables, the specimens were referred to the International Standard for annealed copper, which has a resistivity such that the resistance of a wire of uniform section 1 m. in length and weighing 1 grm. is 0·15328 ohm at 20 deg. C. The resistivity is expressed in microhms per centimetre cube. In both sand and chill castings, both before and after annealing, the figures obtained were rather variable and bear no direct relation to the oxygen content of the samples. It would appear that the results of this test, as of other tests described, are more controlled by the soundness of the casting than by small variations in its chemical composition. One point, however, is worthy of note, namely, that both sand and chill castings possess a better electrical conductivity after annealing than in the "as cast" state. In the case of rolled bar the effect of oxygen on the electrical conductivity is clearly shown, and it is seen that the conductivity falls steadily as the oxygen content increases. Annealed specimens always possess an appreciably higher conductivity than specimens in the "as rolled" condition. The conductivity of copper containing only 0·015 per cent. of oxygen is shown to be over 102 per cent. of the International Standard, and this value falls to about 96 per cent. in the case of copper containing 0·36 per cent. of oxygen.

A further series of tests has been carried out to determine the electrical resistivity at 65 deg. C., which may be regarded as the maximum temperature to which a conductor should usually be heated. The results show that

* Abstract of a paper read at the meeting of the Institute of Metals, Manchester, on September 12, 1923.

the conductivity is considerably lower at this higher temperature. The oxygen-rich copper is, however, relatively a better conductor at 65 deg. C. than at 20 deg. C., though the difference is but slight.

MACROSTRUCTURE.

The macrostructures of castings of all compositions used throughout the research show that the crystal structure of these castings is quite large, except in the case of the copper containing 0·02 per cent. of oxygen, and the poor mechanical properties associated with the sound castings containing 0·09 per cent. to 0·21 per cent. of oxygen is probably partly due to this coarse crystal structure. Crystal size, as evidenced by the macrostructures of 1-in. diameter chill castings, is much smaller. In most cases the radial crystals commonly found in chill castings do not extend completely to the centre of the ingot, although in the samples high in oxygen such crystals are sometimes found. It is thought that the shorter solidification range of the copper having a high oxygen content may be responsible for the greater tendency for radial crystals to be produced in such metal. It was, however, observed that the macrostructure at different ends of the same test-piece was not always of the same character. Since mould temperatures were controlled fairly carefully, differences in structure are probably due to such differences in the pouring temperature as cannot be avoided in pouring small masses of metal. The different structures are accompanied by widely different mechanical properties, since a casting possesses a tensile strength of 13·4 tons per square inch and an elongation of 10 per cent., while another possesses a tensile strength of 16·6 tons per square inch and an elongation of 25 per cent. Both castings were practically free from unsoundness, as is indicated by the density figure obtained, namely, 8·66 in the case of the former test-piece, and 8·68 in the case of the latter. The type of fracture produced is very different in the two cases. The appearance of the fractures bears a remarkable similarity to that of the etched structures shown in other instances, and it can only be concluded that the differences in the properties are due to the differences in the crystal structure of the alloy. This is further borne out by a photomicrograph of these alloys which refers to the weaker casting, and by another which refers to the stronger. In the former the eutectic structure is well developed, while in the latter the eutectic is practically irresolvable. The evidence suggests that in the case of the copper represented in the former, the rate of solidification has been much slower than that of the metal represented in the latter, probably because the former has been cast from a higher temperature.

The macrostructures of the 1$\frac{9}{16}$ in. diam. chill-cast billets used for rolling show that the material as cast possesses a uniform structure in the case of copper with low oxygen content, but the high oxygen metals appear to possess a structure consisting of radial crystals that in many cases extend from the outside of the casting nearly to the centre of the billet. It will be noticed that in all cases a well-defined crystal structure is shown on the photographs, although the microstructures show that a large amount of fine-grained eutectic exists in most of these materials. It would appear, therefore, that this eutectic consists essentially of relatively large crystals of copper in which are embedded minute particles of copper oxide, since even in samples which consist almost entirely of eutectic, the well-marked oriented structure is still found.

MICROSTRUCTURE.

Sand-Castings.—The microstructures of the sand-castings show that a cuprous oxide is present in all the samples, although the eutectic structure is not well marked in that containing 0·02 per cent. of oxygen.

Chill-Castings.—In these castings also the eutectic structure is not well marked in the case of materials containing only a small percentage of oxygen, although cuprous oxide is present in considerable quantities.

Rolled Bar.—Microstructures of the samples containing 0·06 per cent. of oxygen and 0·17 per cent. of oxygen as cold-rolled and after annealing show, in two instances, distortion of the copper crystals and the eutectic areas by rolling, and in two others the recrystallisation produced by annealing for half an hour at 700 deg. C.

SOLUBILITY OF CUPROUS OXIDE IN SOLID COPPER.

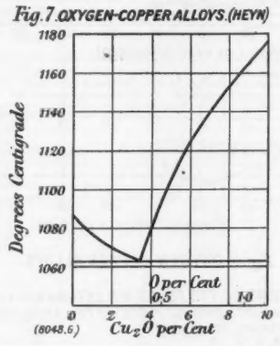
Experiments were undertaken with the object of determining the solubihty of cuprous oxide in solid copper, both at temperatures in the neighbourhood of the solidus and at lower temperatures. A series of samples containing from 0·009 per cent. to 0·104 per cent. was made up, and specimens from these were examined both in the "as cast" condition and after prolonged annealing *in vacuo* for 100 hours at 1000 deg. C. After this long annealing the specimens were quenched in water, in order that any oxide that had passed into solid solution might be retained in solution. Free cuprous oxide was found to be present in all the specimens both in the "as cast" state and after the heat-treatment described above. In the case of the copper containing 0·009 per cent. of oxygen, the amount of free cuprous oxide present was naturally not large, but well-defined particles could be seen when the specimen was examined under a high magnification. The amount of cuprous oxide present suggests that the solubility in solid copper is very appreciably less than 0·009 per cent., and for all practical purposes cuprous oxide may therefore be regarded as insoluble. Microstructures of other specimens, containing high percentages of oxygen, show the effect of prolonged annealing on the structure. It may be noted that during this treatment the fine particles of the eutectic coalesce to form much larger particles. This fact suggests that cuprous oxide is actually slightly soluble in copper, for it is difficult otherwise to understand the mechanism by which such coalescence takes place. Assuming a slight amount of solubility, such coalescence can occur by the normal process of diffusion, the small particles gradually becoming dissolved and reprecipitated on the larger particles. Such solubility can, however, only be extremely small.

The equilibrium diagram of the oxygen-copper alloys over the range 0 to 1·2 per cent. oxygen, which has been investigated by Heyn, is reproduced in Fig. 7. In view of the results obtained, relating to the solubility of cuprous oxide in solid copper, this diagram may be regarded as a correct representation of the constitution of the alloys of copper with oxygen.

GENERAL SUMMARY OF THE RESULTS.

The results described in the present investigation indicate that oxygen has a relatively small effect on the properties of copper, and is neither seriously deleterious nor remarkably beneficial. The mechanical properties are not much affected by small quantities of oxygen, and a metal containing as much as 0·1 per cent. differs very slightly from pure copper. The electrical conductivity, which is usually profoundly affected by the addition of small quantities of an impurity to a pure metal, does not fall rapidly, and values exceeding 100 per cent. of the International Standard are obtained in all annealed materials containing less than 0·1 per cent. of oxygen. The relatively small effect of oxygen is without doubt due to the fact that the solubility of the oxide in solid copper is extremely low—so low, in fact, that for all practical purposes the oxide may be regarded as insoluble in solid copper. The oxygen-bearing metals must therefore be considered as a heterogeneous mixture of pure copper and finely divided particles of cuprous oxide, and within the range of composition investigated the percentage of copper greatly exceeds that of cuprous oxide. The materials consist essentially of a soft ductile copper matrix, in which harder particles of cuprous oxide are distributed, and the properties of the series are such as would be expected from such a mechanical mixture of such constituents.

Fig. 7. OXYGEN-COPPER ALLOYS. (HEYN)



These conclusions, however, are applicable strictly only to pure copper containing oxygen and free from other impurities. The effect of the simultaneous presence of other impurities may be very appreciable, and requires special investigation, for which the present report furnishes a necessary basis.

APPENDIX.

THE EFFECT OF OXYGEN ON COPPER.

Analysis of electrolytic copper used in the research:

Identification Mark.	Oxygen.	Iron.	Nickel.	Copper (by difference).
	Per cent.	Per cent.		Per cent.
A	0·0166	0·0042	Trace	99·98
B	0·0088	0·0069	—	99·98
C	0·0143	0·0038	—	99·98

N.B.—Other elements not found.

Method of Sampling.—The cathodes were cut to a suitable size for subsequent melting, and from the small pieces thus obtained an average sample was taken. The selected sample was then pickled in 30 per cent. nitric acid, well washed in running water, dipped in a 10 per cent. solution of caustic potash, again washed and carefully dried. Fine millings were then taken from the selected pieces, the first cut being in each case rejected. Contamination by handling or lubrication was carefully avoided, and only a light cut taken in order to minimise any chance of oxidation. Similar precautions were taken when preparing samples for the analysis of the different melts.

Estimation of Oxygen in Copper.—The method employed was substantially that of Hampe as modified by Archbutt. The copper, in the form of fine millings, was heated in a hard glass tube for one hour to a red heat in a slow stream of hydrogen, and the water evolved was absorbed in a calcium chloride tube. The hydrogen, obtained from a cylinder of the compressed gas, was passed through a heated silica tube, to remove oxygen, then through concentrated sulphuric acid and a calcium chloride tower. The gas, on leaving the calcium chloride tube in which the evolved water was weighed, passed through a calcium chloride tower and a concentrated sulphuric acid bottle, the latter being a useful indicator of any leak. Heating for a second hour failed to give any additional evolution of oxygen.

CATALOGUES.

Conveyors.—Some ingenious designs of conveyors, elevators and stacking and loading appliances are illustrated in a catalogue received from the Paterson Hughes Engineering Company, Limited, 36, Charlotte-lane, Glasgow.

Fire Hose.—Messrs. Merryweather and Sons, Limited, Greenwich-road, London, S.E.10, send a leaf catalogue of their hose for fire engines. The hose is woven from selected long flax and is made in two strengths, for ordinary pressures and extra-high pressures.

Electric Welding.—The Anglo-Swedish Electric Welding Company, Limited, Greenwich, London, S.E.10, have sent us a 10-page catalogue containing illustrations and test figures of a series of tests on butt welds of steel plates ranging from $\frac{1}{4}$ in. to 1 in. in thickness. These tests are worthy of consideration, both with regard to the soundness of the joints and the effect on the plates.

Pneumatic Tools.—The Consolidated Pneumatic Tool Company, Limited, 170, Piccadilly, London, W., have issued a very useful little catalogue of accessories to their pneumatic tools, comprising such parts as hose, couplings, air cocks, strainers, clamps, &c., and also reamers and other tools. The parts are all illustrated, and sufficient particulars are given for ordering.

Paraffin Engines.—A number of small, fixed and portable, paraffin engines for land or marine work, such as driving winches or propelling small craft, are illustrated in some leaf catalogues received from Messrs. Smart and Brown, Erith, Kent. Complete units are shown for electric generation, pumping, hauling, &c., as well as for agricultural and general work.

Electrical Machinery.—The English Electric Company, Limited, Kingsway, London, W.C., have sent us two more of their carefully-prepared special catalogues: one containing a long list of rotary converter installations, and the other giving a description with dimensions and prices of the firm's iron-clad oil-break switch pillars for small systems or industrial purposes.

Punching Machines.—Many patterns of machines for punching, shearing, notching, mitreing, &c., in which the pressure is applied by means of screws, levers or hand-operated hydraulic rams, are shown in the catalogue issued by Messrs. C. A. Hunton and Sons, 71, Southwark-street, London, S.E.1. Power driven machines are also shown. For many of these machines dies can be supplied to enable angles, tees, joists and other sections to be sheared.

Steam Heating.—A further edition of their pocket size catalogue showing an extensive range of steam heaters for air, water, oil, &c., and also dealing with condensers, evaporators, strainers, filters, purifiers and kindred apparatus, is to hand from Messrs. Royles, Limited, Irlam, Manchester. The catalogue also includes particulars of a very complete range of pipe fittings, valves and other accessories for conducting steam and water.

X-Ray Apparatus.—We have received from Messrs. X-Rays, Limited, 11, Torrington-place, Gower-street W.C.1, a booklet briefly describing the development of the company and giving a long list of hospitals and institutions to which X-ray apparatus has been supplied. A large number of the installations are illustrated and photographs are also reproduced of the factories and workshops where the whole of the apparatus, including the tubes, is manufactured.

Welding Rods.—The Manganese Steel Forge Company, Philadelphia, U.S.A., have sent us several single-leaf circulars dealing with their "Rol-Man" welding rods and electrodes for electric and gas welding. Other leaflets from this firm relate to woven manganese-steel screens for screening coke, coal, stone and other substances, for which high resistance to abrasion is required in the material of the screen.

Steam Engines and Boilers.—A general catalogue of steam engines and boilers received from Messrs. Robey and Co., Limited, Lincoln, shows how extensively this firm meets all the different conditions of work with special designs which aim at providing the type of engine that is most suitable and economical for any given purpose. A careful perusal of this catalogue should convince power-users of the advantage of fully stating their requirements and inviting the engine-makers to advise as to the most suitable type.

Monel Metal Forgings.—Messrs. G. and J. Weir, Limited, Cathcart, Glasgow, have issued a leaf catalogue of monel metal forgings of parts required to withstand the action of superheated steam or corrosive liquids. These parts include rings, cylinders, spindles, bodies and other parts of valves for steam up to 750 deg. F. The metal when forged has a longer life and is less liable to develop small surface defects. An illustration in the catalogue compares the effect of prolonged furnace fire on monel metal rivets and on copper rivets exposed under the same conditions.

Circuit Breaker.—Mr. George Ellison, Perry Bar, Birmingham, informs us that he has re-designed his air-break, totally enclosed circuit breakers, introducing several new features to improve the general efficiency and to facilitate connections and erection. These circuit-breakers are fitted with one handle which suffices for closing and for quick-break hand release, and they are suitable for mills, workshops, non-gaseous mines, and also for public supply mains in place of house service switch fuses. A new catalogue is to hand in which all the required particulars are clearly given.